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PROGRAM ANNOUNCEMENT/SOLICITATION NO./DUE DATE	☐ Special Exception to Deadline Date Policy	FOR NSF USE ONLY
NSF 20-527 12/03/20		NSF PROPOSAL NUMBER **2111936**

FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.)
IIP - SBIR Phase I

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12/03/2020	1	[redacted]	[redacted]	046838184	12/03/2020 8:07am

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[redacted]	☐ A RENEWAL ☐ AN ACCOMPLISHMENT-BASED RENEWAL	YES ☒ NO ☐ IF YES, LIST ACRONYM(S) NASA SBIR

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE	ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE
OPEN SOURCE INSTRUMENTS INC.	Open Source Instruments, I 130 MOUNT AUBURN ST WATERTOWN, MA 02472-3932
AWARDEE ORGANIZATION CODE (IF KNOWN) [redacted]	

NAME OF PRIMARY PLACE OF PERF	ADDRESS OF PRIMARY PLACE OF PERF, INCLUDING 9 DIGIT ZIP CODE
OPEN SOURCE INSTRUMENTS INC.	OPEN SOURCE INSTRUMENTS INC. MA ,024723932 ,US.

IS AWARDEE ORGANIZATION (Check All That Apply): ☒ SMALL BUSINESS ☐ FOR-PROFIT ORGANIZATION ☐ MINORITY BUSINESS ☐ WOMAN-OWNED BUSINESS | ☐ IF THIS IS A PRELIMINARY PROPOSAL THEN CHECK HERE

TITLE OF PROPOSED PROJECT: **SBIR Phase I:A Novel Dense Fiber Array for Astronomical Spectroscopy**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ 240,200	12 months	03/01/21	

THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW

- ☐ BEGINNING INVESTIGATOR
- ☐ DISCLOSURE OF LOBBYING ACTIVITIES
- ☐ PROPRIETARY & PRIVILEGED INFORMATION
- ☐ HISTORIC PLACES
- ☐ VERTEBRATE ANIMALS IACUC App. Date ______
- PHS Animal Welfare Assurance Number ______
- ☒ TYPE OF PROPOSAL Research
- ☐ HUMAN SUBJECTS Human Subjects Assurance Number ______
- Exemption Subsection ______ or IRB App. Date ______
- ☐ FUNDING OF INT'L BRANCH CAMPUS OF U.S IHE ☐ FUNDING OF FOREIGN ORG
- ☐ INTERNATIONAL ACTIVITIES: COUNTRY/COUNTRIES INVOLVED ______
- ☒ COLLABORATIVE STATUS Not a collaborative proposal

PI/PD DEPARTMENT	PI/PD POSTAL ADDRESS
	130 Mount Auburn Street Watertown,MA 02472 United States
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CO-PI/PD				
CO-PI/PD				

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NATIONAL SCIENCE FOUNDATION
Program Solicitation/Instruction Guide Number **NSF 20-527**

SBIR PHASE I - PROPOSAL COVER PAGE

TOPIC	SUBTOPIC LETTER (if any)	TOPIC TITLE
SP	**PS11**	**Space Technologies**

PROPOSAL TITLE **SBIR Phase I:A Novel Dense Fiber Array for Astronomical Spectroscopy**

COMPANY NAME	EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)
OPEN SOURCE INSTRUMENTS INC.	[redacted]

NAME OF ANY AFFILIATED COMPANIES (Parent, Subsidiary, Predecessor)

ADDRESS (Including address of Company Headquarters and zip code plus four digit extension)
Open Source Instruments, I
130 MOUNT AUBURN ST
WATERTOWN, MA 02472-3932

REQUESTED AMOUNT	PROPOSED DURATION	PERIOD OF PERFORMANCE
$ 240,200	**12**	

THE SMALL BUSINESS CERTIFIES THAT:	Y/N
1. It is a small business as defined in the solicitation.	**Y**
2. It qualifies as a socially and economically disadvantaged business as defined in the solicitation. (FOR STATISTICAL PURPOSES ONLY.)	**N**
3. It qualifies as a women-owned business as defined in the solicitation. (FOR STATISTICAL PURPOSES ONLY)	**N**
4. NSF is the only Federal agency that has received this proposal (or overlapping or equivalent proposal) from the small business concern. If No, you must disclose overlapping or equivalent proposals and awards as required by this solicitation.	**N**
5.SBIR: A minimum of two-thirds of the research will be performed by this firm in Phase I. STTR: It will perform at least 40 percent of the work and the collaborating research institution will perform at least 30 percent of the work as described in the proposal.	**Y**
6. The primary employment of the Principal Investigator will be with this firm at the time of the award and during the conduct of the research.	**Y**
7. It will permit the government to disclose the title and technical abstact page, plus the name, address and telephone number of a corporate official if the proposal does not result in an award to parties that may be interested in contacting the small business for further information or possible investment.	**Y**
8. It will comply with the provisions of the Civil Rights Act of 1964 (P.L. 88-352) and the regulations pursuant thereto.	**Y**
9. It has previously submitted proposals to NSF.	**N**
10. It previously submitted this proposal (which was declined) and significant modifications have been made as described in the solicitation.	**N**
11. It has received Phase II awards from the Federal Government. If "yes" provide a company commercialization history in the supplementary documents module.	**N**

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR

NAME **Kevan S Hashemi**

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617-335-3472		

COMPANY OFFICER (FOR BUSINESS AND FINANCIAL MATTERS)

NAME	TITLE	TELEPHONE NO.
James Bensinger	**Treasurer**	**617-610-4319**

OTHER INFORMATION

PRESIDENTS NAME **Kevan Hashemi** YEAR FIRM FOUNDED **2005**

NUMBER OF EMPLOYEES (including Parent, Subsidiary, Predecessor)
AVERAGE PREVIOUS 12 MO.: **5** CURRENTLY: **5**

RESEARCH INSTITUTION NAME
OPEN SOURCE INSTRUMENTS INC.

RESEARCH INVESTIGATOR NAME

RESEARCH INVESTIGATOR TELEPHONE NO.

PROPRIETARY NOTICE: See instructions concerning proprietary information.
Check Here ☐ if proposal contains proprietary information.

PROJECT SUMMARY

Overview:

The objective of this proposal is to build a small Direct Fiber Positioning System consisting of a 4 x 4 array of fibers on a 5-mm grid, each fiber providing a 3.6-mm x 3.6-mm range of motion, with control circuits consuming less than 20 mW per fiber, and accompanied by a monitoring camera viewing the illuminated fiber tips in order to demonstrate a positioning precision of better than 10 μm rms over the course of an hour at both warm and cold temperatures, and in both the horizontal and vertical orientations. If successful, the prototype will demonstrate the feasibility of constructing a much larger array for a large, ground-based telescope, which would then collect the spectra of faint galaxies more quickly than existing technology. Current fiber positioning systems are limited in the number and rate of image capture, thus limiting the speed of discovery. Our fiber positioning system increases the number of objects captured per exposure. In so doing, the instrument will advance the study of the expansion of the universe and the possible role of dark energy in that expansion.

Key words: astrophysics, galaxy formation, fiber positioning, multi-object spectroscopy, faint galaxy, spectroscope, red shift, dark energy, universe mapping, electrical engineering, large telescopes
Subtopic Name: SP11-Other Space Related Technologies

Intellectual Merit:

This Small Business Innovation Research Phase I project will demonstrate a fiber-positioning system that will permit the construction of an astronomical spectrometer with ten times as many measurement fibers as any existing spectrometer. This project's innovation is the change from a mechanically complex fiber positioning system to an electronically complex system. Electronically intensive design lends itself more easily to mass production, long operating life, and inexpensive manufacture. This design permits the fibers to be closely packed and quickly repositioned. It could reduce by decades the amount of time needed for astronomers to answer questions about the nature of dark matter and to come closer to precision cosmology.

Technical challenges of the proposed project include reducing the power consumption of the fiber control circuit, miniaturizing the fiber control circuit, and the development of algorithms to overcome hysteresis and creep in the piezo-electric actuator tubes. Open Source Instruments has electrical engineering expertise, three decades of experience in the design of precision metrology instruments, and the manufacturing resources required to construct and test the proposed instrument. Furthermore, the company will be collaborating with astronomers in academia to ensure that the details of the design are in harmony with the requirements of a practical, large-scale spectrometer.

Broader Impacts:

Verification of our innovation through construction of a prototype will move Open Source Instruments closer to convincing end users that the product works. The end users, who are astronomers and astrophysicists, will be presented with an opportunity to dramatically expand their ability to collect the spectra of distant galaxies and advance their understanding of the universe.

This Phase I grant will permit Open Source Instruments to offer a full-time position to a physicist graduate at a time when few companies are hiring new staff. It will permit us to support domestic manufacturers and our existing professional staff by offering more hours of paid work. If ultimately successful, out project has the potential to bring millions of dollars into Massachusetts with which we would hire technicians, engineers, other skilled labor.
Should we be successful in Phase I, we will invite partnership with MIT Lincoln Labs CCD foundry in the construction of a prototype fiber-positioner and spectrum imaging system. We believe this CCD foundry to be an important resource for the future of astrophysics experiments. This project, in its final version, could provide important work for the foundry.

Finally, the project would provide a less expensive and more efficient research tool for projects often funded by federal dollars through consortia. This fiber-positioning system could allow those consortia to achieve more of their research goals with their available funding.

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*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

Elevator Pitch

Billions of dim galaxies are visible to the largest ground-based telescopes, and each of these galaxies can make a small contribution to our knowledge by providing us with a red-shift measurement. Red-shift measurements from a billion such galaxies would permit a significant improvement in the accuracy of our measurement of the expansion of the universe. For this reason, astronomers are considering how we might construct an instrument capable of measuring the red-shift of fifty thousand galaxies simultaneously, so as to accumulate a billion red-shift measurements in ten years.

Open Source Instruments Inc. (OSI) proposes to develop a compact and cost-effective fiber-positioning system that will make it possible to build a fifty-thousand fiber spectroscope. The spectroscope isolates and collects the light of a single galaxy by placing the tip of an optical fiber at the location of the galaxy image in the focal plane of the telescope. If astrophysicists want to measure the spectra of one billion galaxies in ten years, with one hundred observing days per year, ten observing hours a day, and half an hour per observation, they need fifty thousand (50k) fibers. Current fiber-positioning technologies offer approximately 5k fibers in a 50-cm focal plane. The technology we propose will permit the installation of 50k fibers on a 1.2-m focal plane. At the far end of each fiber, a system of diffraction gratings, lenses, and image sensors obtains the spectrum of the galaxy's light. We propose in Phase I a novel and cost-effective design for the fiber-positioning system for a 50k-fiber spectroscope, not the optical system at the far end of the fibers. Existing technology for diffracting the light carried in a large number of optical fibers [1, 2] appears to be capable of serving a 50k-fiber spectroscope, it is not something we need to design in this proposal.

The Direct Fiber Positioning System (DFPS) we propose is mechanically simple but electrically complex. The mechanics consist only of a piezo-electric tube actuator and a guide tube. The slow and barely-perceptible bending of the actuator tube is magnified by the length of the guide tube to position the fiber, while the fiber's own control circuit delivers ±250-V drive signals to the actuator electrodes. The simplified mechanics permit us to decrease the spacing of the fibers from the existing technology's 10-mm spacing to a 5-mm spacing, allowing us to fit four times as many fibers in the same focal plane as before. High-speed, low-power, serial communication between the guidance system and the individual fiber control circuits permits us to control all fibers simultaneously and continuously regardless of the size or density of the fiber array. The DFPS not only quadruples the fiber density, it permits larger diameter fiber arrays to be built with no increase in adjustment time between exposures.

Commercial Opportunity

The Direct Fiber Positioning System (DFPS) we propose will make possible a fifty-thousand fiber spectroscope capable of measuring the red-shift of one billion distant galaxies in ten years. Astronomers in the United States have already identified the value of such a large-scale spectrographic survey and begun to consider how existing fiber-positioning schemes might be improved so as to make such a large, dense array of fibers possible. This instrument would require a telescope with a large primary mirror and a one-meter focal plane, and the construction of any such telescope raises the cost of implementing the spectroscope to the order of one hundred million dollars. If the fiber array itself can be made for ten million dollars, and guarantee robust and accurate operation for ten years, the fifty-thousand fiber instrument becomes both practical and likely.

Now is the time to put forward a new idea for how to build the next generation of high-density fiber-positioning instruments. It is in the next five years that the comparison of competing proposals for such instruments will take place. The earlier we begin to demonstrate the benefits of our DFPS, the more likely we are to convince the astronomy community of its superiority.

When it comes to surveying a billion dim objects, we believe the superiority of the DFPS over all existing fiber-positioning technologies is clear. Aside from its higher packing density, the mechanics of the DFPS are vastly simpler than all but the original plug-in fiber spectroscope, which permitted movement of the fibers by means of replacing their drilled mounting plates. The DFPS requires no movement other than the slow, slight bending of a piezo-electric tube. The complexity of the DFPS does not reside in its mechanical components, but rather in its electrical components, which must deliver 250-V control signals to all actuator tubes simultaneously. If its electrical challenges can be solved, and we are confident that they can be, the DFPS will stand out immediately as a technology that is far easier to manufacture and far more reliable in the long term than its mechanically complex competitors.

If awarded Phase I funding, we will work closely with academic astronomers to develop the most reliable and cost-effective solution to a widely-acknowledged instrumentation challenge. If we succeed in demonstrating the superiority of our design, we will be in a strong position to be awarded a sub-contract to manage the production of a twenty-million dollar instrument. Our design team has spent the past twenty years working together mass-producing opto-electronic instruments for large physics experiments, and we have a long track record of delivering reliable devices on time and on budget. We have no doubt that, if awarded a contract to build a fifty-thousand fiber spectroscope, we will be able to do so and meet our expenses.

Commercial Market

Our marketing plan is to continue to demonstrate a successful, efficient system so that we will be chosen to manufacture the fiber-positioning system for a fifty-thousand fiber spectroscope. But we have been encouraged by our astronomer collaborators to consider and provide for the installation of thousand-fiber systems for telescopes with smaller focal planes, so as to support studies other than the survey of a billion dim galaxies. Thus, the market for the DFPS will be two-fold: one or two large telescopes and five or ten smaller telescopes. Our long-term goal will to provide a spectroscope with fifty thousand fibers that will survey a billion galaxies. Our short-term goal will be to provide spectroscopes with several thousand fibers to medium sized telescopes at professional installations such as universities or national laboratories.

We do not propose to develop a design for fiber-positioning systems with fewer than a thousand fibers. According to our estimates, the fixed cost of building the auxiliary calibration and mounting system will make the DFPS too costly for smaller telescopes, where the traditional plug-in fiber system will be more economical. Five instruments of several thousand fibers, and one of fifty-thousand fibers provide a market that is more than adequate to keep our company busy and profitable for a decade.

Commercialization Approach

Our strategy is to build instruments that meet specifications provided by their future users, rather than to invent our own specifications and later attempt to sell them into a perceived market. In this case, the need for a fifty-thousand fiber spectroscope is clear and unquestioned, provided it is practical to build. The goal of our research in Phase I is to show that the DFPS can be produced efficiently on a large scale, as described in this proposal. No researcher or academic department, no government consortium will be a customer if they have no faith that the product will work. Because all our work is open-source, we will share all our results, favorable and unfavorable, with all interested parties. If the DFPS is a success, we will prove it to be so.

The bulk of our company's revenue recently arises from our sale of implantable telemetry devices for laboratory animals. We have found in the telemetry research field to date that sales have grown more through word of mouth and sharing at annual meetings than through print marketing. In astrophysics, we believe that any attempt at marketing spectroscope technology would be futile. The only way to convince the community that a particular technology is the best is to present our work at conferences, either directly, or in collaboration with an astrophysics department. We have been presenting our work to physics collaborations for the past twenty years, so we are confident in our ability to present the performance of the DFPS to astrophysicists.

The SBIR Phase I and a II will fund the development and design of the DFPS. Once designed, the product will have a fixed cost for installation, and a per-fiber cost. We are not yet confident in what these fixed and per-fiber costs will be, but we are hoping the fixed cost will be of order one million dollars, and the per-fiber cost will be of order two hundred dollars.

<u>Innovation</u>

We propose a novel system for packing spectroscopic optical fibers in the focal plane of a large telescope. The fibers will be connected rigidly to piezo-electric tube actuators, and their entire movement will be due only to the slight bending of these tubes. The simple mechanical design of the Direct Fiber Positioning System (DFPS) allows us to pack fibers on a 5-mm grid, which is four times the fiber density per unit area than any competing fiber-positioning system [1, 2, 3, 4]. It also permits us to adjust all fibers simultaneously. Compared to the DFPS, all existing fiber-positioning systems are mechanically complex and hindered by laborious adjustment algorithms. The most compact existing fiber-positioning mechanisms, such as the DESI instrument, occupy a 10-mm square per fiber [1], which is four times the area required by one DFPS fiber. The adjustment time per fiber for our system will be an order of magnitude faster than that of the DESI system, as we can move all fibers simultaneously to new positions within a few seconds. Our DFPS will permit the construction of an instrument with fifty thousand (50k) fibers in a 1.2-m diameter focal plane. Because of its mechanical simplicity, the DFPS will allow us to reduce the per-fiber construction cost of such instruments by a factor of two. A 50k-fiber spectroscope would allow astrophysicists to measure the red-shift of one billion galaxies in a single decade. We believe that our DFPS will permit the construction of a 50k-fiber spectroscope at half the cost of any competing system.

A single unit of the DFPS is a piezo-electric tube actuator that is controlled by four voltages applied to four electrodes. The control voltages range from -250 V to +250V with a desired precision ±0.5%. The fiber is held inside a thin-walled hypodermic steel tube that is glued into the end of the actuator tube. The mechanical simplicity of this arrangement, which has no gears, motors, slip-rings, nor any other moving parts other than the slight bending of the actuator tube and the gentle movement of the guide tube, permits us to increase the density of fibers by a factor of four.

While the DESI system shares control signals between fibers, and so can move only a few fibers at a time, the DFPS communicates with all its fiber control circuits independently, allowing us to adjust all fibers simultaneously. Simultaneous adjustment permits us to reduce the time required for re-positioning between exposures, and so increase the number of exposures in each observation period. The DFPS's rapid fiber adjustment and high fiber density make it possible to attain the ambitious goal of measuring one billion red-shifts in a decade. The mechanical simplicity and rapid response of the system requires a far more sophisticated electrical system than those required by existing fiber-positioning systems. The design of a prototype DFPS electrical system will be one of the main tasks of our Phase I work.

The smallest images of faint galaxies on a large telescope's focal plane are of order 50 μm in diameter. We propose to use optical fiber with a 100-μm diameter core. The fibers position must be stable to 10 μm rms within the 3.6-mm square dynamic range of fiber's actuator during an hour-long exposure. All piezo-electric materials exhibit hysteresis and creep. We describe the mitigation of creep, and compensation for hysteresis, in the technical discussion portion of this proposal. Without proper mitigation, creep and hysteresis would undermine our desired fiber-positioning accuracy and precision.

Generating the fiber control voltage is another key technical challenge. The fiber-positioners are designed to be controlled in parallel, which means 200k control voltages must be applied simultaneously to a 50k-fiber system. To generate the control voltages, each fiber needs four high-voltage amplifiers. Each fiber needs a logic circuit to receive instructions, and four eight-bit digital to analog converters to drive the op-amps. These fiber-control circuits, must fit in small space beneath the mounting plane of the actuators. In addition, the circuits must contain a 10-way connector to pug into the bottom of the mounting board. Our initial system for Phase I will be designed to scale, in that the control systems and layout of control electronics will be packed with the same density as the proposed large-scale DFPS.

In terms of intellectual property, Open Source Instruments, Inc. does not carry patents. Any time Open Source Instruments, Inc. has an idea, we build a prototype, write about it, and put it up on the web, thus preventing anyone else from patenting the idea, or even using the idea in their own work without making their own work open source. This process costs us little, requires no lawyers, and is immediate. If a competing company can come up with an idea as quick as we can, they will have to wait six months or more for a formal intellectual property protection process, and their manufacturing will be delayed.

All our work is open source, with copyright held by author under the GNU Public License. Under GNU Public License, any other agency wanting to make use of open-source work cannot do so unless the entire work into which it is included will itself be open-source. This strategy is both aggressive and effective. It does limit the profit we can make on sales of our devices. We are quite happy to give up excessive profit and the ability to exploit our customers. In turn, our customers are happy to know that we will keep our profit margins reasonable and refrain from exploiting them.

The biggest technical challenges we face in demonstrating the feasibility of the DFPS are the electronic challenges we describe above. Designing, building, and demonstrating the functioning of the electronic control system will be the main thrust of our Phase I work.

The Company / Team

Open Source Instruments, Inc (OSI) is an electronics development company whose goal is to build novel electro-mechanical devices that support scientific research. We founded OSI in 2005 to manufacture precision survey instruments for experiments running at CERN (Center for European Research Nuclear). We had designed these survey instruments with Department of Energy funding while working in the Brandeis University Physics Department. High energy physics instrumentation remains an important part of the company's business, but has been surpassed recently by sales of our implantable telemetry devices

The founder and chief executive of OSI, Kevan Hashemi, has a twenty-eight year track record of designing accurate and effective instruments for the scientific community, and managing their mass production for large experiments. Under his management, the Brandeis University Physics Department manufactured thousands of survey cameras that have been operating reliably for the past ten years in the ATLAS experiment at CERN. He designed our implantable telemetry system fifteen years ago, and the company now ships over five hundred implantable devices per year.

We will conduct the development of the high-density fiber array in consultation with academic astronomers. The details of the diffracting spectroscope will be discussed with MITLL. Our Phase I development will focus only on the front-end, dense, fiber array, MITLL has been generous enough to leave a channel for communication open to OSI to discuss how new silicon and germanium image sensors might influence the design of future astronomical spectroscopes, in particular how the ultraviolet, optical, and infra-red sensitivity of these sensors will affect our choice of optical fiber. We believe in Phase II we will be able to include them as a partner in the design and construction of a prototype DFPS suitable for installation on a small telescope.

Our company's business model is provide open-source, cost-effective, and accurate measurement tools requested by scientists. Everything we have ever made and sold was designed at the request of researchers seeking to conduct an experiment they had previously been unable to perform. The higher density of spectrographic fibers provided by the DFPS, and its quicker adjustment time between exposures, will permit astronomers to measure the spectra of ten times as many dim objects per observing hour as any existing spectroscope system.

Our vision for the future is to continue to create electronic tools for research scientists who want them. The DFPS clearly is within this vision.

Revenue History

The primary source of our company's revenue in the past ten years has been our sale of Subcutaneous Transmitters (SCT). These are implantable telemetry devices for use in laboratory animals. We spent five years working on reliable production of such devices in collaboration with University College London, Oxford University, and Harvard University. We started full production of the devices ten years ago, and since then our sales to academic customers have grown steadily, and for the past three years we have been supplying SCTs to a large pharmaceutical company as well. We have approximately $100k in operating cash. Our only creditors are the company directors. We are not beholden to venture capital.

With only 4FTE employees, the company remains small, but the growing number of researchers using our products, and the retention of existing customers, indicate company longevity and point to continued success. In 2011 we sold fifty SCTs. In 2020, our annual sale of SCTs has been roughly 500 pieces, with total telemetry-related revenue of around $250k/yr. The epilepsy research market alone has proved large enough to generate our current sales of 500 SCTs per year, a growth of 25% per year from our starting point of 50 SCTs in 2010. We project a continued growth rate of 25% of sales of this family of devices alone.

Open Source Instrument's success in selling research equipment to scientists verifies our ability to market our devices and conduct sales. Key to our success is creating tools that are effective and for which there is a definite need.

The company was awarded a Phase I SBIR from the NIH NIMH in September 2019 in conjunction with our partners at Cornell University. The award was to create a prototype optogenetic, wireless implantable device for medical research. This grant has changed Open Source Instrument's revenue stream for 2020, primarily we were able to hire additional staff. The fiscal Phase I award ends December 15, 2020 and a report of work completed has been submitted. We currently have a Phase II pending proposal for that project which went through its first round of review November 19-20. We expect to know if we have been awarded Phase II in February 2021.

Below is a chart of Open Source Instrument's revenue since its inception. The company turned a profit in its first year. The company has no debt and no venture capital. The revenue number from 2020 is through November 17 and does *not* include any SBIR Phase I funds, nor any PPP government loans.

Year	Income
2010	$27,693.03
2011	$59,113.10
2012	$115,774.11
2013	$198,716.52
2014	$258,545.88
2015	$240,432.13
2016	$339,879.00
2017	$186,600.00
2018	$250,460.00
2019	$297,950.00
2020	$189,420.00

Technical Discussion and R&D Plan

The number of spectrographic measurements that can be made on a given clear-weather viewing night is dictated by the density of fibers and the speed at which they can be repositioned. The DFPS system is novel because it increases fiber density by a factor of four and increases the speed with which the fibers can be re-positioned. If our objective is to measure the red shift of one billion galaxies in ten years, when there are many more than one billion available for viewing, our fiber-array must be efficient, dense, and quick to re-configure for the next measurement.

Our fibers do not have to be able to move to every point in the focal plane; if they are able to move to at least one target that has not yet been measured. Thus, we propose a 3.6-mm square dynamic range for our fibers, which themselves are spaced on a 5-mm grid. Thus, each fiber covers 52% of the area occupied by its grid square. According to our preliminary calculations, 50% cover of the focal plane is just as effective as 90% cover when we are surveying one billion galaxies. This is because regardless of your field of view of the fiber you can only acquire one object per acquisition. The deeper field surveys that would allow the acquisition of a billion galaxies would have multiple objects in the field of view of one fiber. This means that the benefits of having a large field of view diminish as the number of objects in the field increase.

The way the DFPS gains its advantage over existing fiber-positioning systems is by transforming mechanical complexity into electrical complexity. While the existing systems move only a few fibers at a time, and disable control voltages during exposures, the DFPS generates control voltages continuously. The fiber density increase is enabled by the simplicity of mechanical design. Because electrical complexity is easier to mass-produce than mechanical complexity, the DFPS manufacturing cost per fiber will be less than half that of any other system that has so far been proposed.

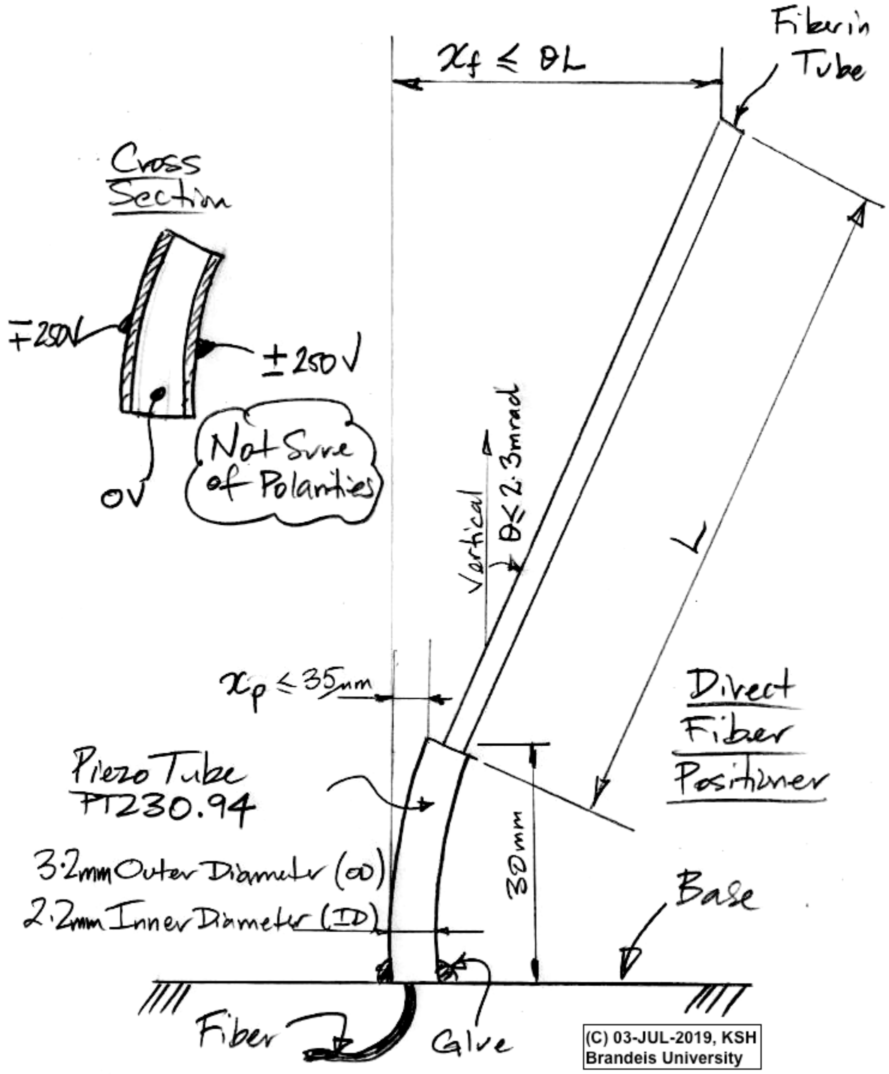


Figure 1: A Prototype Direct Fiber Positioner

Each fiber positioner consists of a hypodermic steel guide tube, a piezo-electric actuator tube mounted on a printed circuit board, an optical fiber with a 100-μm diameter core, and an electronic circuit. The fiber is mounted in a ferrule and the ferrule is held by the end of the guide tube. The guide tube is roughly 300 mm long, although its exact length will be the subject of Phase I research. The base of the guide tube is attached to the top end of the actuator tube, while the base of the actuator tube is soldered to the circuit board so that it is vertical while the circuit board is horizontal. The actuator tube is roughly 40 mm long and 3.6 mm in diameter. The fiber runs down the center of the guide tube, through the actuator tube, and out through a hole in the circuit board.

In Phase I we will first construct a single fiber attached to a larger than scale base and fiber-control circuit. There is only one component of this system that generates mechanical movement: the actuator tube. It bends by a few milliradians, and this movement is amplified by the guide tube to a 3.6-mm square. As point of comparison, the diameter of the DESI positioning system is 10.4 mm and comprised of two rotating brushless motors [1]. Because of their mechanical simplicity, we believe we can manufacture our fiber positioners in large quantities for around $200 per element, and they will be more reliable in a long-term experiment because there are fewer moving parts to fail.

There is, however, a cost to these mechanical simplifications: the electronic control system will be complex and sophisticated. But electronic complexity is more reliable than mechanical complexity, and easier to manufacture in large quantities. We will begin our project by creating a large, single fiber "system" to test, and then we will proceed to miniaturizing the mounting board and fiber-control circuit for a 4 x 4 fiber array.

Challenge: miniaturization of electronics to 5-mm spacing

Each fiber positioner will be equipped with its own 5-mm wide fiber-control circuit that plugs into the underside of the base board and protrudes some 30 mm below the plane of the array. We must fit four ±250-V amplifiers, a logic chip, an oscillator, digital to analog converters, and a ten-way connector in a 5-mm square footprint, while still allowing for a hole in the circuit board for the fiber to pass through.

In an array of 200 x 200 fibers we would control each row of 200 fibers with a four-wire serial interface running along the length of the row. This interface would be able to select and instruct each fiber-control circuit in the row individually. Because serial communication of this sort runs at millions of bits per second, updating the control voltages of all 200 fibers will take tens of milliseconds. Each fiber-control circuit will be equipped with its own micro-power logic chip running an efficient, embedded microprocessor. Upon receiving its identifying number on the serial interface, the fiber controller will receive new X and Y actuator control values, which will produce the inputs to the low-power, ±250-V amplifiers that drive the actuator tubes. There will be four such amplifiers on each fiber-control circuit, one for each electrode on the piezo-electric tube.

Challenge: power consumption less than 20 mW per fiber

Mounting the required circuity in a small package and keeping power consumption below 20 mW per fiber is critical to the success of the system. This is because high heat output could affect the telescope optics. Low power usage is critical to minimizing this effect. While other fiber-positioning systems apply control voltages only temporarily to their mechanical actuators, the DFPS applies its control voltages continuously and requires electrical stability during the entire exposure period. The sustained application of ±250-V control signals during the exposure is a critical difference between our control system and those of existing fiber-positioning systems. Upon the successful conclusion of Phase I we will demonstrate that we can deliver 250-V control voltages with sufficient accuracy, stability, and energy efficiency to permit the construction of a 50-k fiber instrument.

There are numerous details of the DFPS design that we must work out before we propose a final system design. We must select the best material for the guide tube. Our first choice is stainless steel, because it is inexpensive. But we must confirm that stainless steel is sufficiently stiff to provide stable fiber-positioning as a telescope rotates. Carbon fiber tubes are stiffer, but far more expensive to manufacture. Another concern with the tube is that during and after movement the tube must not vibrate.

The fiber positioner could also be affected by temperature changes in a ground-based telescope. Such telescopes are usually installed on mountain peaks where it is cool and dry. At night, the temperature can drop well below freezing. We must measure the effect of temperature upon the hysteresis and creep exhibited by piezo-electric actuators. We will test the array in a deep freezer modified to allow for wires accessing the array and fiber-control circuits inside the freezer, which will replicate cold conditions. Our hope is that temperature will have little effect on the tubes, but if there is a significant effect, we must measure and quantify those to maintain the accuracy of the DFPS.

The ability of the DFPS to place a fiber tip at the image of a faint galaxy in the focal plane of a telescope is contingent upon a thorough and reliable calibration of every fiber in the array with respect to the image plane. Each actuator tube will be placed with some translational and rotational error when it is soldered to its printed circuit board base. The DFPS calibration will measure how the actual fiber tip position varies with control voltage, as to account for variation between fiber assemblies. Without a calibration procedure there would be no way to position the fibers as each one would behave differently from the next.

Challenge: overcoming hysteresis and creep

Before we discuss the current plan for the calibration procedure it is worth discussing two important and detrimental mechanical behaviors exhibited by piezo-electric materials: hysteresis and creep. Both affect how the piezo-electric crystal responds to voltage and voltage changes. Hysteresis in the response of the piezo-electric tube arises because the state of the piezo-electric crystal is a function of the history of its control voltages [5]. These properties significantly complicate our ability to create a map of voltage to position. Ideally, we would be able to create a 1-1 map where each specific voltage level corresponds to one position inside our 3.6-mm square range. Instead we are forced to create a reset procedure that sends the fiber back to a well-defined position and state before we move to the location required for image acquisition. We have begun research on reset procedures, with encouraging initial results, which suggest that the effect of hysteresis can be overcome.

The creep of the actuator tube manifests itself as continued, slight movement of the fiber tip despite no change in voltage applied to the actuator. This continued movement slows with time, and our initial work demonstrated that the movement can be predicted and mitigated by making small adjustments to the control voltages in the minutes following an large movement, stabilizing the fiber position to within $\pm 10\mu$m. Our hope is that we will be able to drive fibers to a known location in the focal plane in one step. We will then check their locations before we begin exposure, by taking an image of the fiber tips with our calibration camera. Our scheme for calibration is not new: it is the same scheme that has been applied with success in all other fiber-based astronomical spectroscopes. We will illuminate the far ends of the fibers so that their tips glow in the camera focal plane, and we take a picture of the glowing tips with one or more cameras placed above and to one side of the focal plane. The calibration of these cameras is a complex and subtle exercise in assembly and geometrical calculation, but we are well-familiar with such work, given our decades working on the alignment systems for large physics experiments, and in any case: this problem has been solved by other experiments with success. We assume, therefore, that such calibration cameras exist, and all we need do is take a picture of the fiber tips to know where they are. If they are near where they are supposed to be, we adjust their position so that they are perfect. But we expect to need no more than one such adjustment prior to each exposure.

We may need to develop a creep and hysteresis calibration for each individual fiber. We will study the variation in hysteresis and creep from one piezo-electric tube to another in our Phase I research. If hysteresis and creep vary with temperature as well as from tube to tube, we will have to resort to more than one calibration camera viewing of the fiber tips between spectroscope exposures.

Our DFPS design assumes that the far end of the fiber will be connected to a spectroscope as well as a mechanism for back-illuminating the fibers for the calibration camera. The design and manufacture of these optical systems will not be a part of our Phase I work, beyond making sure that our choice of optical fiber is consistent with a practical spectroscope and back-illumination system. We will be discussing with MIT Lincoln Laboratories, which houses one of the few remaining CCD foundries in the world, to make sure our DFPS system is capable of taking advantage of the measurement capabilities offered by the latest silicon and germanium image sensors.

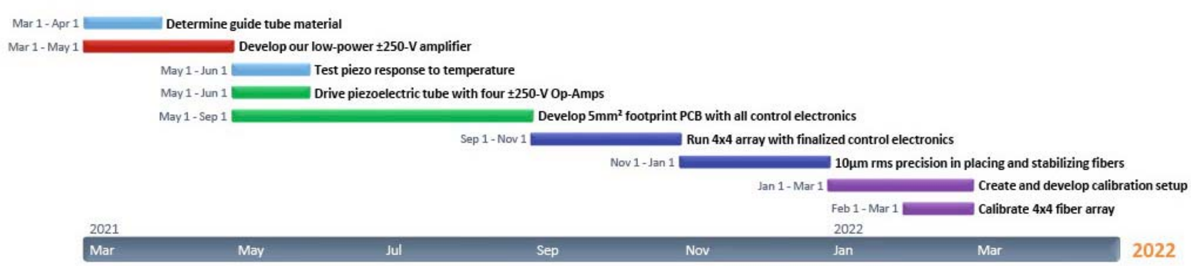
During our Phase I research, we will be consulting with astrophysicists in academia to make sure that the details of our DFPS design remain consistent with the goals of astronomical spectroscopy. We will be in regular communication with Professors Tereasa Brainerd of Boston University and Daniel Eisenstein of Harvard University, both of whom have contributed letters of support to this Phase I application. We also hope to devise, in consultation with Professors Brainerd and Eisenstein, ways to apply our DFPS idea to smaller telescopes, in arrays of thousand fibers rather than the tens of thousands of fibers that motivated our original thinking.

Work Plan

In the graphic below is a schedule for our planned R&D in Phase I. Some of the activities can be completed in parallel while others must be sequential. We will begin by developing our low-power ±250-V amplifier [6] and settle upon a guide tube material so that we can design our first, large fiber positioner. We will choose a piezo-electric actuator and fiber with apertures related to the sought after output. Then we will construct the first, single fiber system on large scale with a non-miniaturized fiber-control circuit, row-differentiator. Part of this process will also be setting up the monitoring camera and software controls.

We will demonstrate precision with this single fiber in horizontal and vertical positions. We will test the ability to move the fiber and have it hold its position in cold and warm environments. Once satisfied with our findings and adjustments, we will proceed with constructing miniaturized fiber-control circuits and 16 moveable fibers for a 5mm grid mounting board.

Once we have built the first 4 x 4 array, we will be able to begin our study of hysteresis and creep in earnest, with the goal of quantifying the best possible procedures for mitigating both effects. Our final milestone is to measure the precision of our positioning system with the help of a camera viewing the fiber tips. We will measure the precision with which we can return to a particular position and hold that position for an hour. Our assumption will be that 10-μm rms precision in placing and stabilizing the fiber tip will almost certainly allow a calibration system to map out how control voltages are related to actual, absolute fiber-tip positions in the telescope focal plane.



Milestones

1. Choose the guide tube material.
2. Choose the actuator tube.
3. Construct a non-miniaturized, single-fiber DFPS.
4. Demonstrate better than 10-μm precision in the single fiber DFPS, in vertical and horizontal orientations, at temperatures 25C and -10C.
5. Construct a miniaturized fiber-control circuit.
6. Construct a 4 x 4 fiber-positioning array with monitoring camera.
7. Demonstrate full range of motion, 10-μm precision, and stability of 4 x 4 array.

Conclusion

Our objective for this proposal is to build a Direct Fiber Positioning System consisting of an array of fibers on a 5-mm grid, each fiber having a 3.6-mm square range of motion and consuming less than 20 mW per fiber, accompanied by a monitoring camera viewing the illuminated fiber tips so as to demonstrate a positioning precision of better than 10 μm rms over the course of an hour at warm and freezing temperature, and in horizontal and vertical orientations. We have the technical ability, the physical resources and the outside guidance to do so.

REFERENCES CITED

[1] LEITNER, D., ET AL. Dark Energy Spectroscopic Instrument (DESI) Fiber Positioner Production, 2018.

[2] SAUNDERS, W., ET AL. MOHAWK: a 4000-fiber positioner for DESpec, 2012.

[3] SHEINIS, A., ET AL. Advances in the Echidna fiber- positioning technology, 2014.

[4] LORENTE, N., ET AL. The TAIPAN Starbugs fibre positioner and spectrograph: integration, commissioning, and initial performance, 2020.

[5] DURAN, L. Properties of Piezoelectric Tube Actuators for use in a Fiber Positioner for a Spectroscopic Telescope, 2019.

[6] HASHEMI, K. Fiber Positioning Circuits (A2089) Manual, 2018.

NSF BIOGRAPHICAL SKETCH

NAME: Hashemi, Kevan

NSF ID: 000842648@nsf.gov
ORCID: 0000-0002-6007-893X

POSITION TITLE & INSTITUTION: President, Open Source Instruments

(a) PROFESSIONAL PREPARATION

INSTITUTION	LOCATION	MAJOR / AREA OF STUDY	DEGREE (if applicable)	YEAR YYYY
Cambridge University	Cambridge, Cambridgeshire	General Engineering	BS	1987
Cornell University	Ithaca, New York	Electrical Engineering	MS	1992

(b) APPOINTMENTS

2004 - present President, Open Source Instruments, Watertown, MA
1995 - present Electrical Engineer & Adjunct Faculty, Brandeis University, Waltham, MA
1992 - 1994 Electrical Engineer, Harvard University, Cambridge, MA

(c) PRODUCTS

Products Most Closely Related to the Proposed Project

1. Amelung C, Bensinger J, Cerutti F, Fabjan C, Hashemi K, Palestini S, Rothberg J, Schricker A, Trigger I. Reference bars for the alignment of the ATLAS muon spectrometer. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment. 2005 December; 555(1-2):36-47. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0168900205017079 DOI: 10.1016/j.nima.2005.08.095
2. Hashemi K, Hurst P, Oliver J. Sources of error in a laser rangefinder. Review of Scientific Instruments. 1994 October; 65(10):3165-3171. Available from: http://aip.scitation.org/doi/10.1063/1.1144545 DOI: 10.1063/1.1144545
3. Aefsky S, Amelung C, Bensinger J, Blocker C, Dushkin A, Gardner M, Hashemi K, Henry E, Kaplan B, Keselman P, Ketchum M, Landgraf U, Ostapchuk A, Rothberg J, Schricker A, Skvorodnev N, Wellenstein H. The Optical Alignment System of the ATLAS Muon Spectrometer Endcaps. Journal of Instrumentation. 2008 November 20; 3(11):P11005-P11005. Available from: https://iopscience.iop.org/article/10.1088/1748-0221/3/11/P11005 DOI: 10.1088/1748-0221/3/11/P11005
4. The Rasnik 3-point optical alignment system. Journal of Instrumentation. 2019 August; Available from: https://doi.org/10.1088/1748-0221/14/08/P08010
5. Amelung C., Barriere J.C., Bauer F., Bensinger J., Fontaine M., Formica A., Gautard V., Giraud P.F., Guyot C., Hart R., Hashemi K., Kortner O., Kotov S., Kroha H., Ponsot P., Schune Ph., Van Der Graaf H.. The ATLAS muon alignment system. Proceedings of the 1st LHC Detector Alignment Workshop. Proceedings of the 1st LHC Detector Alignment Workshop; 2007; c2007. Available from: http://www.scopus.com/inward/record.url?eid=2-s2.0-

84898817426&partnerID=MN8TOARS eid: 2-s2.0-84898817426

Other Significant Products, Whether or Not Related to the Proposed Project

1. Chang P, Hashemi K, Walker M. A novel telemetry system for recording EEG in small animals. Journal of Neuroscience Methods. 2011 September; 201(1):106-115. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0165027011004262 DOI: 10.1016/j.jneumeth.2011.07.018
2. Wright S, Hashemi K, Stasiak L, Bartram J, Lang B, Vincent A, Upton A. Epileptogenic effects of NMDAR antibodies in a passive transfer mouse model. Brain. 2015 November; 138(11):3159-3167. Available from: https://academic.oup.com/brain/article-lookup/doi/10.1093/brain/awv257 DOI: 10.1093/brain/awv257
3. Wykes R, Heeroma J, Mantoan L, Zheng K, MacDonald D, Deisseroth K, Hashemi K, Walker M, Schorge S, Kullmann D. Optogenetic and Potassium Channel Gene Therapy in a Rodent Model of Focal Neocortical Epilepsy. Science Translational Medicine. 2012 November 12; 4(161):161ra152-161ra152. Available from: https://stm.sciencemag.org/lookup/doi/10.1126/scitranslmed.3004190 DOI: 10.1126/scitranslmed.3004190
4. Brown R., Lam A.D., Gonzalez-Sulser A., Ying A., Jones M., Chou R.C.-C., Tzioras M., Jordan C.Y., Jedrasiak-Cape I., Hemonnot A.-L., Abou Jaoude M., Cole A.J., Cash S.S., Saito T., Saido T., Ribchester R.R., Hashemi K., Oren I.. Circadian and Brain State Modulation of Network Hyperexcitability in Alzheimer's Disease. eNeuro. 2018; 5(2). Available from: http://www.scopus.com/inward/record.url?eid=2-s2.0-85058922684&partnerID=MN8TOARS DOI: 10.1523/ENEURO.0426-17.2018

(d) SYNERGISTIC ACTIVITIES

1. I was an important member of a group designing a laser rangefinder at the Harvard High Energy Physics Laboratory in 1993. Our purpose was to build a rangefinder accurate to a tenth of a millimeter that could be manufactured for a few thousand dollars and installed by the hundreds in the Superconducting Super-Collider (SSC). Our work formed part of the successful global effort that produced the economical and effective laser rangefinders available today.

2. I am the principle electrical engineer designing opto-electronic alignment systems for High Energy Physics particle detectors. We designed and built the alignment system of the ATLAS end-cap muon spectrometer. Our design at Brandeis is the CCD Angle Monitor (BCAM), a radiation-resistant, solid-state camera we can calibrate to provide accuracy better than fifty microradians and precision better than five microradians. Thousands of BCAMs are installed in the ATLAS detector. I was the principle inventor of the BCAM.

3. The purpose of my collaboration with Dr. Matthew Walker of the Institute of Neurology (ION) at University College London was to design and build a battery-powered device that could be implanted subcutaneously in a rat and record high-fidelity EEG for two months. In 2010 we made such a device, which made possible a series of experiments at ION in which tens of thousands of hours of high-fidelity EEG was collected from freely-moving, co-habiting animals.

NAME: James R. Bensinger

POSITION TITLE & INSTITUTION: Research Professor of Physics, Brandeis University

A. PROFESSIONAL PREPARATION
(see PAPPG Chapter II.C.2.f.(i)(a))

INSTITUTION	LOCATION	MAJOR/AREA OF STUDY	DEGREE (if applicable)	YEAR (YYYY)
Bucknell University	Lewisberg, PA	Physics	B.Sc.	1963
University of Wisconsin	Madison, WI	Physics	Ph.D.	1970

B. APPOINTMENTS
(see PAPPG Chapter II.C.2.f.(i)(b))

From - To	Position Title, Organization and Location
2020-retired	Research Professor, Brandeis University
1996-2000	Chair, Brandeis University Physics Department
1989-	Professor, Brandeis University
1980-1989	Associate Professor, Brandeis University
1974-1980	Assistant Professor, Brandeis University
1973-1974	Research Associate, Brandeis University
1970-1973	Instructor / Assistant Professor, University of Pennsylvania

C. PRODUCTS
(see PAPPG Chapter II.C.2.f.(i)(c))
Products Most Closely Related to the Proposed Project

"Reference Bars for the Alignment of the ATLAS Muon Spectrometer" C. Amelung, J.R. Bensinger, et al., Nuclear Instruments and Methods A555, 36-47 (2005).

"The Optical Alignment System of the ATLAS Muon Spectrometer Endcaps," C. Amelung, et al., JINST 3: P11005, 2008.

"The ATLAS Experiment at the CERN Large Hadron Collider," The ATLAS Collaboration, JINST 3:S08003, 2008.

"System test of the ATLAS muon spectrometer in the H8 beam at the CERN SPS," The ATLAS Muon Collaboration, Nucl. Instrum. Meth. A593:232-254,2008. May 2008.

"Study of the ATLAS MDT spectrometer using high energy CERN combined test beam data," C. Adorisio, et al., Nucl. Instrum. Meth. A598:400-415, 2009.

Other Significant Products, Whether or Not Related to the Proposed Project

Contributions to the ATLAS Experiment

1. Design of the on-chamber gas flow system for MDT chambers
2. Integration of the endcap muon system
3. Design and construction of the muon endcap alignment system
4. Mechanical construction of the big and small MDT wheels
5. Recently: Level-2 US Muon Subsystem Manager

D. SYNERGISTIC ACTIVITIES
(see PAPPG Chapter II.C.2.f.(i)(d))

High Energy Physics Collaborations:

1. Multiparticle Spectrometer (MPS), Brookhaven Laboratory 2. Venus Detector at Tristan, KEK
3. Collider Detector at Fermilab (CDF), Fermilab
4. SDC Experiment, SSC, Texas
5. ATLAS Experiment, CERN
6. LZ Dark Matter Experiment, Homestake Mine, SD

SUMMARY PROPOSAL BUDGET

YEAR 1

ORGANIZATION **OPEN SOURCE INSTRUMENTS INC.**				FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Kevan S Hashemi**				AWARD NO.		
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)	
1. **Kevan S Hashemi - Chief Engineer**	6.00	0.00	0.00	**60,000**		
2. **James Bensinger - Physicist, Project Manager**	1.00	0.00	0.00	**14,000**		
3.						
4.						
5.						
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**		
7. (**2**) TOTAL SENIOR PERSONNEL (1 - 6)	7.00	0.00	0.00	**74,000**		
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)						
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**		
2. (**1**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	9.00	0.00	0.00	**45,000**		
3. (**0**) GRADUATE STUDENTS				**0**		
4. (**0**) UNDERGRADUATE STUDENTS				**0**		
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**		
6. (**1**) OTHER				**6,000**		
TOTAL SALARIES AND WAGES (A + B)				**125,000**		
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**0**		
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**125,000**		
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)						
TOTAL EQUIPMENT				**0**		
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**0**		
2. INTERNATIONAL				**0**		
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ **0** 2. TRAVEL **0** 3. SUBSISTENCE **0** 4. OTHER **0**						
(**0**) TOTAL PARTICIPANT COSTS				**0**		
G. OTHER DIRECT COSTS						
1. MATERIALS AND SUPPLIES				**43,000**		
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**		
3. CONSULTANT SERVICES				**0**		
4. COMPUTER SERVICES				**0**		
5. SUBAWARDS				**0**		
6. OTHER				**0**		
TOTAL OTHER DIRECT COSTS				**43,000**		
H. TOTAL DIRECT COSTS (A THROUGH G)				**168,000**		
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **indirect cost rate (Rate: 40.0000, Base: 168000)**						
TOTAL INDIRECT COSTS (F&A)				**67,200**		
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**235,200**		
K. FEE (FOR SBIR/STTR PROGRAMS: MAXIMUM ALLOWABLE FEE = 7% of J)				**5,000**		
L. TOTAL COST AND FEE (J + K)				**240,200**		

PI/PD NAME **Kevan S Hashemi**	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Kevan Hashemi**	Date Checked	Date Of Rate Sheet	Initials - ORG

1 ***ELECTRONIC SIGNATURES REQUIRED ONLY FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

Cumulative

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months)	
	Proposed	Granted
AWARD NO.		

ORGANIZATION
OPEN SOURCE INSTRUMENTS INC.

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Kevan S Hashemi

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Kevan S Hashemi - Chief Engineer	6.00	0.00	0.00	60,000	
2. James Bensinger - Physicist, Project Manager	1.00	0.00	0.00	14,000	
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (2) TOTAL SENIOR PERSONNEL (1 - 6)	7.00	0.00	0.00	74,000	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (1) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	9.00	0.00	0.00	45,000	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (1) OTHER				6,000	
TOTAL SALARIES AND WAGES (A + B)				125,000	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				0	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				125,000	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				0	
2. INTERNATIONAL				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
(0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				43,000	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				43,000	
H. TOTAL DIRECT COSTS (A THROUGH G)				168,000	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				67,200	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				235,200	
K. FEE (FOR SBIR/STTR PROGRAMS: MAXIMUM ALLOWABLE FEE = 7% of J)				5,000	
L. TOTAL COST AND FEE (J + K)				240,200	

PI/PD NAME
Kevan S Hashemi

ORG. REP. NAME*
Kevan Hashemi

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

C*ELECTRONIC SIGNATURES REQUIRED ONLY FOR REVISED BUDGET

Budget Justification

A. Senior Personnel
Salaries and wages are based on standard rates/salaries which are comparable to others doing similar effort.

Kevan Hashemi, Chief Engineer, will work 6 months on this project at an annual rate of $120,000. His responsibilities will include project oversight, electrical design, experiment design, and mechanical design.

James Bensinger, Physicist, will work 1 month on this project at an annual rate of $168,000. Dr. Bensinger brings a wealth of project management experience to Open Source Instruments. He will guide the project in the hands of the professional and technical staff.

For contributing personnel we request a fringe benefit rate of 7.65% for FICA, which is included in our indirect request, line I.

B. Other Personnel
Salaries and wages are based on standard rates/salaries which are comparable to others doing similar effort.

Jordan Kaufman, Technician, has a bachelors degree in physics and is interested in working as an engineer. He has been with Open Source Instruments since August 2020, however, he worked at CERN with Dr. Bensinger for a year prior and also with Kevan in the Brandeis University engineering lab of the Physics department. At Brandeis, Jordan conducted preliminary experiments on the piezo electric tube concept, which is the basis of this proposal. Jordan will work 9 months effort at an annual rate of $60,000. His responsibilities will include electronic design, mechanical design, technical execution of construction, experimentation, testing of light reception, and analysis of results.

Andrey Dushkin, Mechanical Engineer, has more than 30 years experience in mechanical and material engineering and is the head mechanical engineer for the physics department at Brandeis University. He will be asked to design parts for the fiber positioning system which must be machined. In particular, he will apply design expertise to fiber mounting.

C. Fringe Benefits
Open Source Instruments charges fringe benefits as an indirect cost. The fringe benefits will be 7.65% for each employee and health benefits for those who need it. We will charge these as an indirect cost.

D. Equipment
No large pieces of equipment will be purchased under this grant.

E. Travel
No travel expenses will be charged under this grant.

F. Participant Support Costs
There are no participant support costs in this proposal.

G. Other Direct Costs
The following materials and supplies are requested to complete the proposed work:

Equipment and Materials	Quantity	Unit	Cost Each	Total Cost
piezoelectric tubes	30	tube	$400	$12,000
optical fiber	1000	meter	$5	$5,000
hypodermic steel tube	40	foot	$100	$4,000
circuit board fabrication	10	lot	$1,000	$9,000
miniature connectors	50	piece	$50	$2,500
metal fixtures	4	piece	$2,000	$8,000
Disposables: epoxy, wipes, solv	1	lot	$2,500	$2,500
polishing equipment for fibers	1	lot	$20,000	Existing Inventory
data acquisition electronics	1	set	$3,000	Existing Inventory
data acquisition computer	1	piece	$1,000	Existing Inventory
bare die LEDs for back-lighting	100	pieces	$10	Existing Inventory
			TOTAL	**$43,000**

I. Indirect Costs
Open Source Instruments, Inc. requests and indirect cost rate of 40%

K. Fee
A fee to Open Source Instruments of not more than 7% of direct costs is requested $5,000

*PI/co-PI/Senior Personnel Name: James R. Bensinger

*Required fields

Note: NSF has provided 15 project/proposal and 10 in-kind contribution entries for users to populate. Please leave any unused entries blank.

Project/Proposal Section:

Current and Pending Support includes all resources made available to an individual in support of and/or related to all of his/her research efforts, regardless of whether or not they have monetary value.[1] Information must be provided about all current and pending support, including this project, for ongoing projects, and for any proposals currently under consideration from whatever source[2], irrespective of whether such support is provided through the proposing organization or is provided directly to the individual. Concurrent submission of a proposal to other organizations will not prejudice its review by NSF, if disclosed.[3]

Please enter your support entries so they are grouped together based on the "Status of Support" and are in the order of Current, Pending, Submission Planned, and Transfer of Support from top to bottom

[1] If the time commitment or dollar value is not readily ascertainable, reasonable estimates should be provided.
[2] For example, Federal, State, local, foreign, public or private foundations, non-profits, industrial or other commercial organizations or internal funds allocated toward specific projects.
[3] The Biological Sciences Directorate exception to this policy is delineated in PAPPG Chapter II.D.2.

Projects/Proposals

1. *Project/Proposal Title : Please note, currently Professor Bensinger is retired and has no grant or in-kind support. This document submitted per requirement, but intentionally left blank.

*Status of Support : (•) Current ( ) Pending ( ) Submission Planned ( ) Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

2. *Project/Proposal Title :

*Status of Support : ( ) Current ( ) Pending ( ) Submission Planned ( ) Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

Projects/Proposals

3.*Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

4.*Project/Proposal Title :

*Status of Support : ○Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

Projects/Proposals

5. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

6. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

Projects/Proposals

7.*Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

8.*Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

Projects/Proposals

9. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

10. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

Projects/Proposals

11.*Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

12.*Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

Projects/Proposals

13. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

14. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

Projects/Proposals

15. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

In Kind Contributions

*Required fields

In-Kind Contribution Section:

Current and Pending Support also includes in-kind contributions (such as office/laboratory space, equipment, supplies, employees, students). If the in-kind contributions are intended for use on the project being proposed to NSF, the information must be included as part of the Facilities, Equipment and Other Resources section of the proposal and need not be replicated in the individual's Current and Pending Support submission. In-kind contributions not intended for use on the project/proposal being proposed that have associated time obligations must be reported below. If the time commitment or dollar value is not readily ascertainable, reasonable estimates should be provided.

Please enter your support entries so they are grouped together based on the "Status of Support" and are in the order of Current to Pending from top to bottom

1. *Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

2. *Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

*Dollar Value of In-Kind Contribution: $

3. *Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

4. *Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

*Dollar Value of In-Kind Contribution: $

5. *Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

6.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

*Dollar Value of In-Kind Contribution: $

7.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

8. *Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

*Dollar Value of In-Kind Contribution: $

9. *Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

10.*Status of Support : ◯ Current ◯ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

*Dollar Value of In-Kind Contribution: $

NSF CURRENT AND PENDING SUPPORT

PI/co-PI/Senior Personnel: Hashemi, Kevan

NSF ID: 000842648@nsf.gov

PROJECT/PROPOSAL CURRENT SUPPORT

1. Project/Proposal Title: U.S. ATLAS Operations: Discovery and Measurement at the Energy Frontier

   Proposal/Award Number (if available): 1624739

   Source of Support: National Science Foundation

   Primary Place of Performance: SUNY Stony Brook University

   Project/Proposal Support Start Date (if available): 2020/10

   Project/Proposal Support End Date (if available): 2021/09

   Total Award Amount (including Indirect Costs): $226,041

   Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project:

Year	Person-months per year committed
2020	3
2021	9

2. Project/Proposal Title: An optogenetic brain implant with EEG monitoring and response for mice Phase I

   Proposal/Award Number (if available): GRANT12832361

   Source of Support: National Institute of Mental Health NIH

   Primary Place of Performance: Open Source Instruments

   Project/Proposal Support Start Date (if available): 2019/09

   Project/Proposal Support End Date (if available): 2020/12

   Total Award Amount (including Indirect Costs): $258,000

   Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project:

Year	Person-months per year committed

Year	Person-months per year committed
2020	4

PROJECT/PROPOSAL PENDING SUPPORT

1. Project/Proposal Title: An optogenetic implant with monitoring and response for mice - Phase II

   Proposal/Award Number (if available): GRANT13201483

   Source of Support: National Institute of Neurological Disorders and Stroke NIH

   Primary Place of Performance: Open Source Instruments, Inc.

   Project/Proposal Support Start Date (if available): 2021/03

   Project/Proposal Support End Date (if available): 2023/03

   Total Award Amount (including Indirect Costs): $1,600,000

   Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project:

Year	Person-months per year committed
2021	5
2022	7
2023	2

Facilities and Equipment

Open Source Instruments

Open Source Instruments has its laboratory and manufacturing facility at 5 Pratt Ave, Waltham, MA. Our 2,000 square foot, rented space has an open floor plan. It is well lit with natural and artificial light. There are eight distinct work stations in the space, which are comprised of a work-bench surface, seating, magnifier lights, computers, and specialized equipment. We have three general-purpose electronic assembly stations and an additional three stations dedicated to the manufacture of subcutaneous transmitters. Other stations include an optical fiber stretcher and radio frequency testing space with Faraday enclosure.

The facility is large enough to include space for storing items related to manufacturing such as electronic components, flux, potting epoxy, manufactured parts ready for sale, and Faraday enclosures. There are also shelves for disposable items like mixing tips, paper containers, and wipes. The space is large enough to absorb growth in both projects and people.

In its laboratory, Open Source Instruments has all equipment necessary for electronic design and assembly. Items include: fiber polishing equipment, computers, six soldering irons at the electronic assembly stations, three complete telemetry set-ups for testing and programming transmitters, optical fiber stretcher to heat and divide optical fibers to create tapers, oscilloscopes, a vector voltmeter, photometers.

The Open Source Instruments Inc. billing and correspondence address is 130 Mt. Auburn Street, Watertown, MA 02472. This is the address under which our paperwork is filed and it is where we receive our mail. Accounting, invoicing, and bill paying happen from the Mt. Auburn Street address.

Information Resources

Open Source Instruments is fortunate to have the ear of members of MIT Lincoln Labs (MITLL) who have specialized knowledge in the area of charge-coupled devices (CCDs), including geranium CCDs. As the dense fiber array is developed, we will seek information about CCD requirements and abilities from this source in order to guide development of the front-end of the project. Any initial design collecting faint light ought to take into account where the output will go, what will happen in the spectrometer and how the spectrum data will be collected and analyzed.

As one of the only CCD foundries manufacturing, we anticipate including MITLL in a Phase II proposal for continued development of our complete spectroscope. We feel fortunate to have a relationship with the organization because the ultimate success of our spectroscope will depend upon the ability of the back-end to accurately collect a dense set of faint, detailed light spectrums.

Additionally, as resources we have astrophysicists with a breadth of experience and knowledge in large telescopes and spectroscopy: Dr. Tereasa Brainerd of Boston University, and Dr. Daniel Eisenstein of Harvard University. When the astrophysics knowledge at Open Source Instruments is exhausted, we will turn to these professors for information regarding needs of the research community. In deed, to date they have already been exceedingly helpful in defining the scope of the current proposal. These professors will be a source of information for us about what the end user is seeking in a spectroscope. In a Phase II proposal, we anticipate engaging them and their teams to test our device.

Data Management Plan

Below are the guiding principles and practices for data produced in every project at Open Source Instruments, Inc.

1. Products of Research – Open Source Instruments will have several types of data as a result of this proposal. Data will be the result of testing physical processes and procedures, new designs of circuits, software, and computational output. These products are available to all of our collaborators and advisors

2. Data Formats and Standards – Data produced at Open Source Instruments will be in several different formats. Primarily, however, data are stored, presented, and linked to on our website, opensourcesintruments.com. When we store data in hardcopy notebooks, we later copy them to our website. Our policy is to transfer all data on our personal computers to our website. Any advisor or collaborator seeking information may freely and independently search the company website. If any measurements, design files, or drawings are missing from the website, we will upload them upon request.

3. Dissemination, Access and Sharing of Data – A large portion of all of Opens Source Instrument's designs and software are available online at the company website. The website is broken into sections by project. The section addressing research and development related to the project in this proposal has been added to the website and is populated with our preliminary work results. All software is available upon request, or uploaded regularly to GitHub. Researchers are invited to download and personalize our programs for their own research.

All our work is open source, with copyright held by author under GNU Public License. Under GNU Public License, any other agency wanting to make use of open-source work cannot do so unless the entire work into which it is included will itself be open source. This strategy is both aggressive and effective at protecting our company's intellectual property. Any time we develop a new instrument, we build a prototype, write about it, and present it immediately on our website. This immediate publication prevents any other institute or company from patenting the idea. They are free to use the idea, but only if they make the entirety of their own product open-source.

4. Re-Use, Re-Distribution and Production of Derivatives – There are no disclaimers about the re-use of data on our website. We have notice of Copywrite under GNU Public License The metadata for figures produces are included in the log of work generated by the engineer and uploaded to the company website. Anyone may quote or use data we generate to further their research. Again, all our work is protected by GNU Public License as is stated clearly on our published documents. GNU Public License states that, should someone modify or use information from something with GNU Public License Copywrite, that will also be governed by GNU Public License.

5. Archiving of Data – The plan for archiving data produced are to maintain the company website on which the bulk of the data is published. This is a long term solution in so far as the company remain viable and in-tact. Because the website is housed off-site, it is safe from water damage and fire. Further, the company managing the site back-up information regularly.

HARVARD COLLEGE OBSERVATORY
60 Garden Street, Cambridge, MA 02138-1516

November 23, 2020

To whom it may concern:

I write to support the development of novel technologies to address the problem of dense, efficient, high-precision fiber positioning for high-multiplex astronomical multi-fiber spectroscopy, as featured in the proposal "A Novel Dense Fiber Array for Astronomical Spectroscopy" by PI Kevan Hashemi from Open Source Instruments.

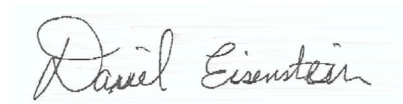
I am Daniel Eisenstein, Professor of Astronomy at Harvard University. I currently serve as Chair of the Harvard Department of Astronomy. My main research focus for the past twenty years has been the study of cosmological large-scale structure as revealed by multi-object spectroscopy. I served as Director of the Sloan Digital Sky Survey III (2007–2014) and as co-Spokesperson of the Dark Energy Spectroscopic Instrument collaboration (2014–2020), both facilities based around state-of-the-art multi-fiber spectroscopy.

Efficient multi-object spectroscopy requires a mechanism to select the desired objects from the wide-field focal plane of the telescope. Current fiber positioning systems work well, but are limited to relatively sparse samples, both in number and spacing. A denser array of positioners (i.e., with smaller pitch) will be critical to acquiring larger samples of faint galaxy spectroscopy: we cannot realistically make the telescope focal planes much bigger, and current surveys already take 5 years to complete. We need to increase the number of objects captured per exposure, so as to make more efficient use of the field of view provided by the telescopes.

With larger samples, extragalactic astronomers and cosmologists could acquire precise distances to faint distant galaxies, constructing 3-dimensional maps of the Universe and studying the evolution of galaxies. This is important for the study of dark matter and dark energy as well as the physics of galaxy formation. Such surveys have been given high priority in previous roadmaps for federally-funded astronomical and high-energy physics research, and I anticipate that there will be ongoing community support for such work. I also note that the largest survey facilities are typically led by federal agencies, a robust technological solution for fiber positioning might lead to instruments of smaller scope and lower cost that are often funded by the consortia of universities, states, and research institutions that operate telescopes.

The proposers contacted me for information regarding future needs in astrophysics instrumentation. My experience with large telescopes and the science drivers for next-generation spectroscopic surveys can inform the direction of their work. The PI and his team may turn to me as a resource for information where their astronomy expertise is limited.

Sincerely,



Dr. Daniel Eisenstein
Professor of Astronomy
Chair, Department of Astronomy
Harvard University
deisenstein@cfa.harvard.edu
Phone: (617) 495-7530

Boston University Institute for Astrophysical Research

725 Commonwealth Avenue
Boston, Massachusetts 02215
T 617-358-0603 F 617-353-5704
www.bu.edu/dbin/iar/

November 23, 2020

To the National Science Foundation,

I am writing in strong support of a Phase I proposal from Open Source Instruments, Inc. that seeks to develop a compact, cost-effective optical fiber array for use with ground-based telescopes (Proposal Title: Novel Dense Fiber Array for Astronomical Spectroscopy, PI: Kevan Hashemi). As envisioned, this new system would increase the number of fibers that are used in telescopic fiber arrays by a full order of magnitude. Such a system would result in a significant increase in the efficiency with which astronomers could obtain spectra of distant galaxies. This, in turn, would lead to a vastly better understanding of two of the greatest puzzles of modern cosmology: the nature of dark energy and the nature of dark matter.

To date, some of the best constraints on the nature of dark energy and dark matter have come from large redshift surveys such as the Sloan Digital Sky Survey. Studies of Baryon Acoustic Oscillations and Weak Gravitational Lensing have allowed astronomers to place direct constraints on the equation state parameter of dark energy and on the growth of structure in the universe. To improve upon the current constraints and reach the goal of "precision cosmology" (for which the error bars on the cosmological parameters would shrink to well under 1%), astronomers need to be able to obtain the spectra of vastly more galaxies than have been obtained so far. The dense fiber array proposed by Open Source Instruments, Inc. holds the promise to significantly advance studies of both Baryon Acoustic Oscillations and Weak Gravitational Lensing by allowing astronomers to efficiently obtain the galaxy redshifts that will be necessary for truly precision cosmology.

Should the proposed new technology prove feasible, I believe many privately-owned observatories would be interested in using the fiber array for scientific purposes, particularly for spectroscopic follow-up of the photometric galaxy catalogs from PanSTARRS (which has already released the largest volume of astronomical data ever collected) and from the upcoming Legacy Survey of Space & Time (LSST) that will be conducted by the Vera Rubin Observatory. My own institution is a permanent capital partner in the Lowell Discovery Telescope (LDT), a 4.3m telescope owned by Lowell Observatory in Arizona. The LDT partnership has often expressed an interest in adding highly-efficient, multi-object spectroscopy to the existing suite of instruments, and something such as the proposed fiber array could greatly enhance the scientific return from the LDT.

Yours sincerely,

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