COVER SHEET FOR GRANT PROPOSALS
State Board of Education

SBOE PROPOSAL NUMBER: (to be assigned by SBOE)	AMOUNT REQUESTED: $75,000

TITLE OF PROPOSED PROJECT: Optical sensors for harsh environment

SPECIFIC PROJECT FOCUS: Currently there is a need in the market place for extreme environment, (temperatures> 800^{o}C, high radiation, high pressure etc), optical fiber sensors based on Bragg grating technology as they are immune to electromagnetic interference and can be deployed in hard to access location. Commercial Bragg gratings are typically written on optical fibers using ultraviolet light source. However, commercial UV written grating sensors do not survive harsh environment due to a multitude of factors including composition of the fiber and the writing technology. Boise State University (PI) has been working on determining the composition of fibers that can survive under harsh environments as a part of a collaborative proposal with Idaho National lab. In addition, the PI's team has also designed a novel multiparameter sensor that can measure pressure, temperature and external condition at the same time. The university, through prior research, has discovered that Bragg gratings written by femto-second infrared (fs-IR) laser on optical fibers have demonstrated stability and has performed with high reliability under harsh environments. Fs-IR lasers based optical Bragg gratings on fibers can be used to make both high temperature and radiation resistant sensors. Currently Idaho does not have the capability to create these sensors leading the university to send their fibers to China and Australia to get them manufactured. A local company Fiber guide also has vested interest in this research as they would like to be the leading industry in harsh environment sensing. Purchasing this laser at Boise State University will allow Fiber Guide and the university to manufacture and sell harsh environment sensor.

PROJECT START DATE: 7/1/19	PROJECT END DATE:6/30/20
NAME OF INSTITUTION: Boise State University	DEPARTMENT: Office of Sponsored Programs
ADDRESS: 1910 University Dr., Boise, Idaho 83725	
E-MAIL ADDRESS: osp@boisestate.edu	PHONE NUMBER: 208-426-4420

	NAME:	TITLE:	SIGNATURE:
PROJECT DIRECTOR/PRINCIPAL INVESTIGATOR	Dr. Nirmala Kandadai	Assistant Professor	Not required
CO-PRINCIPAL INVESTIGATOR	N/A		

NAME OF PARTNERING COMPANY: Fiber Guide Industries	COMPANY REPRESENTATIVE NAME: Devinder Sai

	NAME:	SIGNATURE:
Authorized Organizational Representative	Kimberly Page	Kimberly Page (signature) Digitally signed by Kimberly Page Date: 2019.05.28 11:37:14 -06'00'

1. Name of the Principle Investigator driving the project

Nirmala Kandadai

2. Name of Idaho public Institution

Boise State University

3. Prior Proposal submitted

No

4. Executive Summary

Currently there is a need in the market place for optical fiber Bragg grating based sensors in extreme environments (temperatures> 800^{o}C, high radiation, high pressure, etc) as they are immune to electromagnetic interference and can be deployed in hard to access spaces. Commercial ultraviolet (UV) laser written grating sensors do not survive harsh environments due to the composition of the glass in the fiber and the UV laser used for writing. Boise State University (PI) has been working on determining the composition of fibers that can survive under harsh environments as a part of a collaborative proposal with Idaho National Labs. In addition, the PI has also designed a novel multiparameter sensor that can measure pressure, temperature and external refractive index at the same time. The university, through prior research, has discovered that Bragg gratings written by femto-second infrared (fs-IR) laser on optical fibers have demonstrated stability, radiation resistance and reliability under harsh environments. Currently Idaho does not have the capability to create these sensors leading the university to send their fibers to China and Australia to get them manufactured. A Caldwell based fiber optic company, Fiberguide Industries, has vested interest in this research as they would like to be the leading industry in harsh environment sensing using optical fibers. Purchasing this laser at Boise State University will allow Fiberguide and the university to manufacture and sell these sensors locally.

5. Project Objective and Total Amount Requested

The project objective of this proposal is aligned with Goal 1 Objective 1a, Objective 1b, Goal 2 Objective 2a and Goal 3 of the higher education research strategic plan submitted by the higher education research council. In this proposal, we seek to develop harsh environment optical fiber sensors through the procurement of a femtosecond infra-red laser etching tool to write Bragg gratings (Goal 1 Objective 1a). The high energy femtosecond laser, in contrast with commercial writing technology, creates a permanent change (damage) in the glass structure, changing its refractive index and making the sensor robust in high temperatures and radiation environments. The sensors are of interest to both local industry Fiberguide Industries (Goal 2 Objective 2a) and Idaho National Lab (Goal 1 Objective 1b).

Boise State University (PI), in their current DOE collaborative grant with Idaho National Lab, has identified specific glass composition in fibers that can survive under harsh environments such as nuclear reactor. If awarded, we will create Bragg grating sensors on these specialty fibers using femtosecond laser system and test them under harsh environments (high temperature and radiation). We have also successfully designed a novel multiparameter reflective sensor (submitted for invention disclosure with office technology transfer) based on Bragg grating, known as reflective long period grating, capable of measuring multiple parameters such as temperature, pressure, refractive index simultaneously as opposed to a conventional fiber Bragg grating which can only measure single parameter. This work will be commercialized by Fiberguide Industries (Goal 3), who currently send their fibers to Australia for fabrication. In order to accomplish these goals we will need a femtosecond laser system described in the budget. The **cost of the laser system** is approximately **$140,000;** the **amount requested** through IGEM is **$75,000**, the difference will be paid for **with institutional resources**.

6. MARKET OPPORTUNITY

This project will target high temperature and harsh environment sensing markets where conventional electronic and optical sensors cannot compete. There is a large gap in the market place for sensors that can survive long term inside jet engines, nuclear power plants, etc. Conventional electronic sensors tend to be destroyed very easily in these environments. These shortcomings are prevalent and in many cases the industries have no sensors leading to inaccurate information, inefficiencies and loss.

According to research on optical sensors market, the market share of optical sensors is projected to reach 3.47 billion dollars by 2023 from 1.13 billion dollars in 2016 at a CAGR of 15.47% between 2017 and 2023. The research conducted identified that major drivers for the market growth will be the suitability for sensing in harsh environment and constant technological developments in optical sensors. The major industries interested in this technology are aerospace, defense industry, nuclear, environmental, space and construction.

As currently there is a lack of active sensing, the main competition for such a technology will be passive sensors such as melt wires. The predominant barrier for market entry will be deployment of these technology. Our industry partner, Fiberguide have certain solution for deployment of these sensors and plan to commercialize the technology.

7. THE TECHNOLOGY AND PATH TO COMMERCIALIZATION

The technology being developed is creating novel optical fiber sensors that can survive harsh environments using femtosecond laser etched Bragg grating. Our work has sparked the interest of a local company Fiberguide and the company plans to commercialize the technology. Fiberguide is expanding in to the fiber optic sensing market. This segment of fiber optics is growing at ~2x the standard fiber optics market ~18%. Fiberguide, in 2017 acquired Micron optics who predominantly build optical fiber sensors. This has added several positions and ~$500k in annual revenue. Expanding the product line into radiation and temperature hardened areas is expected to double the revenue of this area, to a minimum of $1Million in short order (<1 year). This will add 2 assembly level personnel to the fiber sensing build area.

Fiberguide currently has several projects that require both standard FBGs, as well as radiation hardened FBGs. These assembly projects have the potential to add an additional $1Million in revenue/year. Progress on these projects has been slow and hampered due to the difficulty in dealing with international product sources of questionable quality. In addition, Fiberguide is developing a user-level product that would requires femtosecond etched FBG sensors. Current development efforts are focused on development of a system which would be utilized for infrastructure monitoring. This system would be installed on a suspect bridge or other civil infrastructure and provide monitoring of temperature and strain in real time feeding the data to customer's existing monitoring software system in addition to being available as a cloud stream. Development of this system will eventually require much larger numbers of sensors than are currently in production. A local Boise source for these critical components will add value both through the purchase of FBGs from Boise State University, as well as revenue and jobs coming back to Fiberguide through sales of the complete system. Their minimum sales target for this system is an additional $5 Million with a planned launch date of 1-2 years.

8. Institutional Support

1. The institution will cost share the purchase of the laser through Dr. Kandadai's start-up funds.

2. The manufacturing of these sensor require three parts, specific composition of the fibers, the laser and a precision motor stage. Currently the PI's research group has successfully identified fibers that can survive harsh environment. The group also has the necessary precision motor

stage required to support the laser system. Adding the laser system will complete the entire manufacturing process

3. Boise State University will provide the labs pace as a part of startup package to Dr. Kandadai which will house the laser system.

4. Boise State University will be supporting personnel (Dr. Kandadai's effort and a Graduate Student) to set up the laser system and fabricate the sensors.

5. Boise State University supports this grant as the laser system can be used to develop other technologies such as laser ablation of smart material to generate novel material ink, laser ablation of bio film to kill bacteria in food industry and Laser micro-machining to support lithography. The resultant work will be interdisciplinary and in collaboration with Material Science Engineering and Mechanical and Bio Medical engineering.

9. COMMERCIALIZATION PARTNERS (PUBLIC OR PRIVATE)

The commercialization partner identified is Fiber Guide Industries. Fiber guide, founded in 1977 is part of Halma company is a leading supplier of specialty optical fiber and optical fiber assemblies in over 30 countries. Fiberguide Industries (FGI) has set up a facility with dedicated staff in Caldwell to build and package Fiber BG sensor arrays and has licensed patents for FBG based sensors. It has so far spent over $500,000 in setting up facilities and training staff to build FBG based sensors. FGI established a production line for FBG assemblies approximately 1 year before the start of this application, which allows for the utilization of FBGs in the production of FBG-based sensors for infrastructure strain, temperature and acceleration sensing. These are sold under the brand name of "Micron Optics". This investment involved the hiring of one production supervisor, and approximately half of one assembly level technician. It also involved the purchase of test equipment and inventory (parts) in excess of $500,000. In the last year, FGI has received multiple requests to generate radiation hardened fibers for various applications. As a result, FGI has a strategic direction to develop a standalone product for this market. This project will help facilitate the launch and development of this product for radiation hardened environments and has the potential to add several million dollars in revenue. FGI is also dependent on this grant to secure source FBGs for use in high stress, temperature and radiation environments. Currently, there is no established source for these FBGs – which means that their expansion into these markets is hampered. . With the success of this application, FGI will be able to expand this production line further as well as purchasing future inventory components (FBGs) from BSU rather than external sources.

Boise State University has an established relationship with Fiber Guide. Fiber Guide has provided internships to Boise State University students and has been supporting the DOE grant between Boise State University and Idaho National lab developing radiation resistant fibers by providing optical fiber samples and training to the graduate students. The PI has taught a class for Fiber Guide employees in Fall'18 and will be teaching a workshop during Summer'19 to the company. The synergistic relation has been mutually beneficial.

If the grant is awarded Fiberguide Industry will be supportive by providing the following:

- Providing sensor specifications to Boise State University
- Providing fibers for FBG etching
- Obtaining fabricated sensors from Boise State University and preparing them for testing (polish, splice the connectors to the sensors, etc)
- Provide the testing facility and personnel support to test the sensor performance. Analyze the results and provide BSU with an updated set of specifications
- Test the final sensor modules for commercial purposes

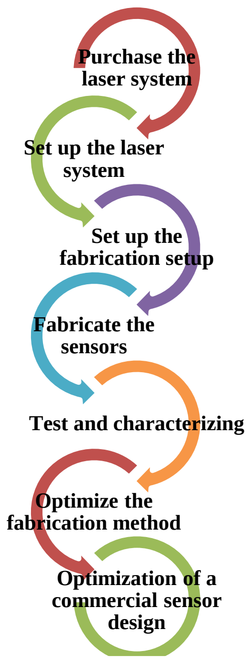


Figure 1: Project Plan

10. Specific Project Plan

Project objectives for creating the sensor is shown in the above figure 1. To be successful the tasks are outline in the next paragraph along with the required personnel for it

Task 1: Purchase the laser system: The laser system will be purchased from Spectra Physics SHG one.

Task 2: Set up the laser system: Once installed the laser system will be tested and analyzed at Boise State University

Task 3: Set up the optical fabrication set up: The PI currently has the motorized stage necessary for fabricating these sensors. The optics set from the laser system and the motors will be set up to get the system setup for fabrication

Task 4: Fabricate the sensors: The fabrication of the sensors both, based on conventional Fiber Bragg Grating design and the designed Long Period Grating sensors will be fabricated on optical fibers and their performance will be characterized

Task 5: Testing and characterizing: The fabricated sensor will be tested under harsh environment, such as extreme temperatures (>500 ^{o}C) and under radiation environment, by leveraging the partnership with Idaho National Lab.

Task 6: Optimization of the fabrication method: The sensor fabrication will be optimized for various parameter of a. the laser system such as pulse duration, beam energy and b. the optics system that will focus the laser on to the

Task 7: Optimization of a commercial sensor design: The sensor fabrication will be optimized for the required commercial design from Fiber guide.

<u>Team</u>: The principal investigator, Dr. Nirmala Kandadai, has over 10 years of experience in developing femtosecond lasers. Prior to Bose State University, she worked in National Energetics for three years building and developing ultrafast lasers. At Boise State University, she has been developing optical fibers that can survive inside the nuclear reactor. She will bring in her expertise to study operation and etching capability of the ultrafast Infra-red laser tool.

11. CRITERIA FOR MEASURING SUCCESS:

METRICS TO MEASURE PROJECT SUCCESS	COMPLETE BY	SPECIFIC TASK
1. PROCURE A WORKING LASER	3 MONTHS	TASK 1 AND TASK 2
2. FABRICATE THE FIRST SAMPLE CAPABLE OF MEASURING TEMPERATURE	6 MONTHS	TASK 3 AND TASK 4
3. TEST THE SENSORS AT HIGH TEMPERATURE	7 MONTHS	TASK 5
4. OPTIMIZE THE SENSORS FOR THE NOVEL DESIGN	9 MONTHS	TASK 6
5 CREATE A TEST SENSOR FOR FIBER GUIDE	12MONTHS	TASK 7

SUMMARY PROPOSAL BUDGET

Name of Institution: Boise State University

Name of Project Director: Dr. Nirmala Kandadai

A. PERSONNEL COST (Faculty, Staff, Visiting Professors, Post-Doctoral Associates, Graduate/Undergraduate Students, Other)

Name/ Title	Salary/Rate of Pay	Fringe	Dollar Amount Requested
PI Dr. Nirmala Kandadai: no funding request. PI Kandadai will manage the Boise State research and be responsible for communication with ISBE and project deliverables.	$0	0%	0

% OF TOTAL BUDGET:	0%	SUBTOTAL:	$0

B. EQUIPMENT: (List each item with a cost in excess of $1000.00.)

Item/Description	Dollar Amount Requested
SPONE-8-SHG (single equipment laser system): This laser system will be used to create femtosecond etched Bragg gratings in the fiber. Such a grating created can be deployed in harsh environments such as high temperatures and radiation. The harsh environment sensor created opens a market and has generated interest from both national lab and industry.	$75,000
	$75,000

C. TRAVEL:

Dates of Travel (from/to)	No. of Persons	Total Days	Transportation	Lodging	Per Diem	Dollar Amount Requested
					SUBTOTAL:	$0

D. Participant Support Costs:

	Dollar Amount Requested
1. Stipends	
2. Other	
SUBTOTAL:	$0

E. Other Direct Costs:	Dollar Amount Requested
1. Materials and Supplies:	
2. Publication	
3. Consultant Services	
4. Computer Services	
5. Subcontracts	
6. Other (specify nature & breakdown if over $1000)	
SUBTOTAL:	$0
F. Total Costs: (Add subtotals, sections A through E) TOTAL:	$75,000
G. Amount Requested: TOTAL:	$75,000
Project Director's Signature: Not Required	Date: N/A

INSTITUTIONAL AND OTHER SECTOR SUPPORT

(add additional pages as necessary)

A. INSTITUTIONAL / OTHER SECTOR DOLLARS

Source / Description	Amount

B. FACULTY / STAFF POSITIONS

Description

C. CAPITAL EQUIPMENT

Description

D. FACILITIES & INSTRUMENTATION (Description)

1. **Laboratories:**

1.1. Fiber Optics and Integrated Research Lab

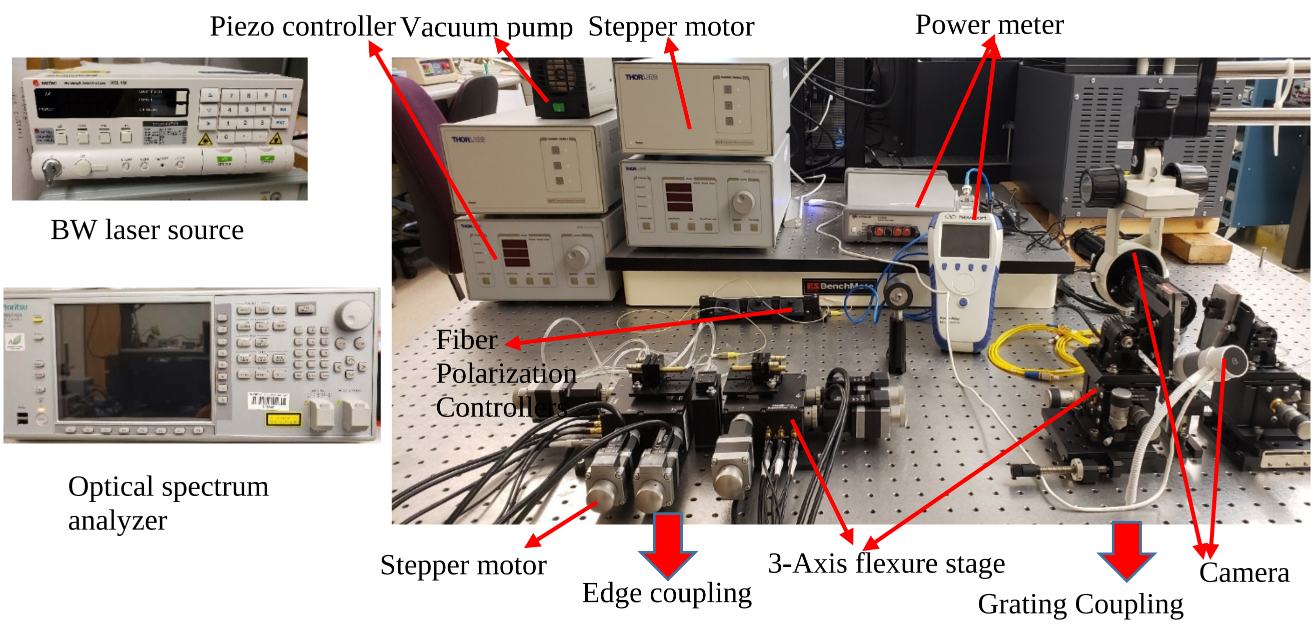
Boise state university's Fiber Laser And Integrated photonics Research (FLAIR)lab currently has two specific capabilities

1. Characterizing and calibrating typical optical sensors from 600nm – 1650nm.

Equipments include six different laser systems

1. 1 Santec tunable laser 1500nm-1600nm
1. 2 Amonics broadband laser 1550-1650nm
1. 3 Thorlabs Fiber coupled laser (1300nm)
1. 4 RPMC 20W laser at 808nm
1. 5 Helium Neon laser at 600nm
1. 6 Optilab laser system at 1000-1100nm

The lab has an optical spectrum analyzer that can receive light between 600nm-1700nm in addition to In GaAs photodiode and Newport power meter with multiple head.The group has a Micron Hyperion interrogator which is used for Bragg grating calibration and an Opsen's white light interferometer to characterize and calibrate Fabry-Perot Sensors. The lab has a tube furnace that can reach 1200^{O}C.
In addition, the group has grating coupler set up and edge coupler set up as shown in FigureX that can guide light into photonic waveguides and characterize them. The set up includes two sets of motorized three axis stepper motors, vacuum pump, a camera that aids in look at the fiber being coupled.



2. Infrared Thermography

FLAIR lab currently has a set-up of infrared thermography as shown in Figure yyya and yyyb. The schematic for the experiment is shown in Figure xxx. The lab has two different methods of heating a fuel: surface heating from a high power laser and thermal heating from a furnace. The high power laser provides the differential heating of the surface, where-as the furnace creates the necessary thermal background to allow the radiation to be in the range of the detector (IR camera).

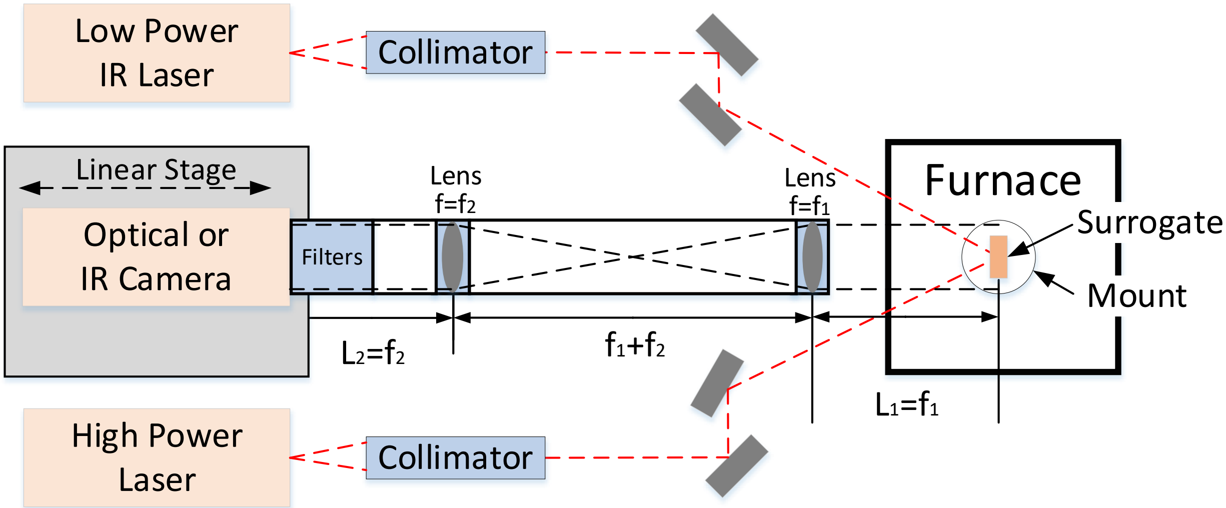


Figure a: Imaging Setup.

Two lasers are used in the setup. The low power laser has a wavelength of 1310 nm and is used only to aid in focusing and setting up the field of view of the IR camera. The high power laser at 808nm is used to differentially heat the surface of the target to image the sample

The collection optics uses a two-lens setup where the distances are determined by the focal lengths of the lenses. The magnification is $M = f_2/f_1$ where f_1 and f_2 correspond to the focal length of the lenses. The lab contains different sets of lens system allowing a change in magnification if required. The laser used to heat the sample is at a wavelength of $\lambda = 808$ nm and a high pass filter with a cutoff wavelength at $\lambda = 1000$ nm is used to ensure that the image is from the blackbody radiation of2 the sample. Two different cameras are used in this setup: a Zeiss optical and a Hamamatsu IR camera. The IR camera is used to image the blackbody radiation from the target and can record images up to 1700nm. The optical camera is mainly used to aid in focusing and setting up the field of view of the setup. The entire imaging setup inside a safety enclosure is shown in Figure d.

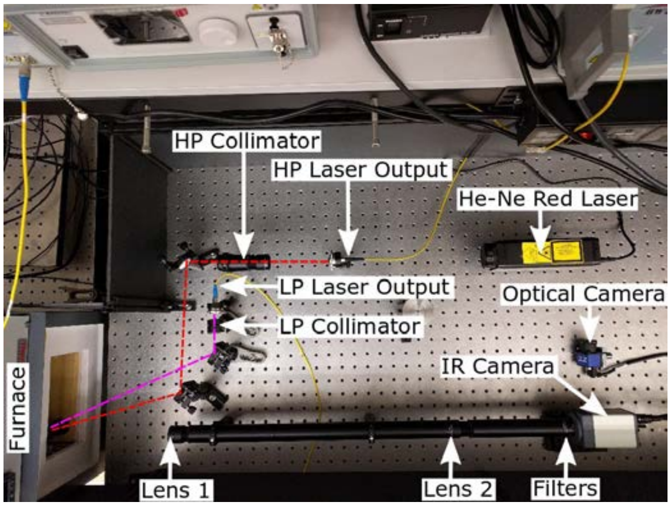


Figure d. Experimental setup. The camera with the long optical tube is on the bottom. The High power laser path is the red dotted line and the low power laser path is the magenta dotted line. The third laser on the upper right is used to aid in the high power laser optical alignment. The optical camera is also shown, sitting next to the IR camera when not in use.

Biographical Sketch:

Nirmala K. Kandadai	Assistant Research Professor, Electrical and Computer Engineering, Boise State University, Boise Idaho

EDUCATION/TRAINING

INSTITUTION	LOCATION	MAJOR	DEGREE & YEAR
Chaitanya Bharathi Institute of Technology	Hyderabad, India	Electrical and Electronics Engineering	B.E 2004
University of Texas	Austin, TX	Electrical and Computer Engineering	M.S 2009
University of Texas	Austin, TX	Electrical and Computer Engineering	PhD 2012

RESEARCH AND PROFESSIONAL EXPERIENCE:

PERIOD	APPOINTMENT	INSTITUTION & LOCATION
2004-2006	Software Engineer,.	Satyam Computer Services Limited, India
2007-2008	Co-Op	Texas Instruments, Dallas, Tx
2012-2013	Postdoctoral Fellow	University of Texas at Austin, Austin Texas.
2013-2016	Laser Scientist	National Energetics, Austin, Texas
2016-Present	Research Assistant Professor	Boise state University

SELECTED PUBLICATIONS:

1. S. Rana, **N. Kandadai**, and H. Subbaraman, “Highly Sensitive, Polarization Maintaining Photonic Crystal Fiber Sensor Operating in the THz Regime,” Photonics, 5, 40 (2018)
2. B. Wilson, S. Rana, H. Subbaraman, **N. Kandadai**, T. Blue, “Modeling of the Creation of an Internal Cladding in Sapphire Optical Fiber Using the 6Li(n,α)3H Reaction,” IEEE. Journal. Lightwave. Technol, 36 (23) 5381-5387 (2018)
3. J. Huff, P. Davis, A. Christy, D. Kellis, **N. Kandadai,** Z. Toa, G. Scholes, B. Yurke, W. Knowlton, R. Pensack, Nonradiative Decay Governs Exciton Lifetimes in DNA-Templated Constructs of Strongly-Coupled Cyanine Dyes (Accepted in Journal of Applied Chemistry)

4. E.Gaul, **N.Kandadai**, et al,"Petawatt Contrast Measurement of the Texas Petawatt Laser", Optics Infobase Conference Review, 2014.
5. H. Thomas, **N. Kandadai**, K.Hoffmann et al., Intense X-ray interactions with Xenon Clusters, Phys. Rev.Lett. 108, 133401 (2012)
6. **N. Kandadai**, K. Hoffmann, H. Thomas, et al, Explosions of Methane Clusters Driven by Intense X-Ray FEL Pulses, in Quantum Electronics and Laser Science Conference, OSA Technical Digest (CD) (Optical Society of America, 2011), paper QTuC2.
7. **N. Kandadai**, K. Hoffmann, H. Thomas et al, Explosions of Xenon Doped Methane Clusters in Intense X-Ray FEL Pulses,in CLEO:2011 - Laser Applications to Photonic Applications, OSA Technical Digest (Optical Society of America, 2011), paper JThB45.
8. B.Erk, K. Hoffmann, **N. Kandadai** et al ., Observation of Shells in Coulomb Explosions of Rare-Gas Clusters ,Physical Review A, Phys. Rev. A 83, 043201 (2011)
9. K. Hoffmann, B. Murphy, **N. Kandadai** et al, Explosion of clusters in XUV, Physical Review A, Phys. Rev. A 83,043203 (2011)
10. K. Hoffmann, **N. Kandadai**, H. Thomas, et al, Explosions of Clusters in Intense X-Ray Pulses, in Quantum Electronics and Laser Science Conference, OSA Technical Digest (Optical Society of America, 2010), paper JFA2
11. K Hoffmann, B Murphy, B Erk, A Helal, **N. Kandadai**, J Keto, et al. in High Energy Density Physics (2010)
12. Garcia de Gorordo, Alvaro; Hallock, Gary A.; **Kandadai, Nirmala**, "Photon-assisted Beam Probes for Low Temperature Plasmas and Installation of Neutral Beam Probe in Helimak," in American Physical Society, 50th Annual Meeting of the Division of Plasma Physics, November 17-21, 2008

CURRENT RESEARCH SUPPORT

TITLE	SPONSOR	AMT	PERIOD	MOS.
Measurement of Structure and Measurement of Structure and Chemistry of Fuel Surrogates Using Electrochemical Impedance Spectroscopy and IR Thermography	Battelle Energy Alliance	209,250	8/16/18-9/30/19	0.5
Nuclear Instrumentation	Battelle Energy Alliance	465,000	9/4/18-9/30/19	2.0
Kandadai: CAES Summer Visiting Faculty Program Participant	Battelle Energy Alliance	21,815	5/15/19-8/15/19	1.57

fiberguide industries
THE PHOTONICS PACKAGING COMPANY

www.fiberguide.com

3409 East Linden St • Caldwell, ID 83605 • Phone: 208 402 2056 • e-mail: dsaini@fiberguide.com

May 20th 2019

Idaho State Board of Education Research Council

I am writing in support of Nirmala Kandadai's application for HERC funds for the proposal "Fabrication of Optical Sensors for Harsh Environments".

Fiberguide Industries is a company that has for over four decades been known for innovation and specializes in the production of custom optical fibers, optical fiber sensors and fiber assemblies in many applications including nuclear, oil &gas, astronomy, medical, life sciences, amongst others. We are based in Caldwell Idaho where we manufacture fiber assemblies and sensors. We also have a fiber draw facility in New Jersey. Fiberguide has recently expended it's facility in Idaho from 27,000 sq ft to 48,000 sq ft and is in the process of setting up a fiber draw facility in Caldwell.

Fiberguide is known for the manufacture of optical fibers with metal coatings that can be used for high temperature applications and in harsh environments. We currently manufacture fiber Bragg grating (FBG) sensors for various application around the world. One of the issues limiting the use of these sensors is the ability for them to survive in high temperature and harsh environments. Industry is crying out for sensors that can survive in these environments. Having these types of sensors would be a great differentiator for Fiberguide against competitors and therefore we are actively pursuing new technologies and capabilities that would allow us to compete better in the market place. Dr. Kandadai's proposal for developing sensors for harsh environments is perfect for our needs and we would ultimately like to commercialize them once the technology has been proven.

Having a facility at BSU that has the capability to manufacture fiber Bragg gratings using femto-second laser technology would be of great help to Fiberguide. Sensors could be manufactured locally and students would be trained for local industry. Femto-second laser technology opens up a multitude of applications in various markets beyond sensors and therefore is a wave of the future that would allow collaboration with other local industries and BSU.

Sincerely yours,

Dr Devinder Saini
VP of Technology
Fiberguide Industries