PREPROSAL TO

U.S. DEPARTMENT OF ENERGY

A RESEARCH PROGRAM FOR DEVELOPMENT AND FIELD TESTING OF FIBER-OPTIC SENSORS FOR MONITORING GEOLOGICAL ENVIRONMENTS

by
Hawaii Institute of Geophysics
and
Hawaii Natural Energy Institute

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2525 Correa Road
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Proposed Duration: 1 year (7/1/92 - 6/30/93)
Estimated cost: $206,908

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Recently, a program was started at the University of Hawaii to develop long-length fiber-optic probes and sensors for use in field (on-site) monitoring of industrial processes and geological phenomena. This research has been directed along two lines: (1) to develop a fiber-optic temperature sensor which could be used to obtain real-time information at high temperatures (ca. 300 C) in deep geothermal wells and (2) to develop a remote Raman probe (RRP) capable of identifying crystalline chemical compounds and dissolved species in hostile or inaccessible environments.

Both of these projects have achieved unqualified success. The geothermal sensor was completed and successfully tested in a geothermal steam well on the island of Hawaii (Sharma et al., 1990). This field test demonstrated the potential of fiber-optic technology for real-time geothermal well logging. The use of the RRP was successfully demonstrated through the detection of Raman spectra of weak Raman scatterers at lengths of 100 m (Schoen et al., 1992a). This probe utilized special filters and optics capable of being used in constricted spaces of only a few millimeters.

This proposal seeks to address major issues leading to improvement of fiber-optic geothermal probe and sensor designs for use in wells of 3 km (or more) depth. The main issue to be addressed is the increase in fiber-optic probe length. Current design limitations related to fiber-optic dispersion and attenuation at visible wavelengths have limited such probes to 300 meters (Sharma et al., 1990). We thus seek, in this work, to develop fiber-optic sensors that operate at near-infrared (NIR) wavelengths where optical fibers have highest transmission. This is the same spectral range used by the communications industry for transmitting data at distance up to 200 km through optical fiber without the need for repeater amplifiers.

We have already begun testing (Schoen et al., 1992b) of a fiber-optic temperature sensor whose useful temperature response is based upon NIR phosphorescence of neodymium-doped glass when excited with laser light of wavelength 1064 nm (Nd:YAG laser) or 836 nm (diode laser). We conservatively estimate that 25 times more power can be delivered using this wavelength range than is possible with the 488.0 nm (argon-ion laser) wavelengh used in the above study. Another advantage of this (or other potential) NIR sensor is that its response can be excited using NIR diode lasers. The small size, rugged design and low cost of such lasers make them ideal for field studies such as proposed here. A major part of this work will therefore be devoted to field testing of these novel temperature sensors.

Additional problems to be addressed include the testing of probe materials for durability in hostile (hot, wet, and chemically reactive) environments and the investigation of extending the useful length of the RRP to 3 km for some limited but useful purposes such as the characterization of the ratio of gaseous to liquid water in hydrothermal or geothermal environments. Optical fibers and associated components usable at temperatures up to 300 C are commercially available. These can be made chemically resistant by armoring with a stainless steel jacket. Although such armored fiber-optic cables are not commercially available, such a jacket can be applied to an existing optical fiber through special order. The development of a 3 km long RRP is a more difficult problem and thus will primarily be a laboratory effort.

The University of Hawaii has unique technical capabilities and expertise for carrying out this project. This includes NIR Fourier-Transform and CCD spectroscopic capabilities and experience in development and field testing of fiber-optic sensors. In addition, through the Hawaii Natural Energy Institute, the University of Hawaii is involved in drilling exploratory geothermal wells on the big island of Hawaii. The availability of funding from DOE for technological development such as proposed here will greatly accelerate this project. The proposed fiber-optic sensors could have potential impact upon other energy-related endeavors including oil exploration and monitoring of nuclear reactors. The U.S. is lagging behind in this area of high technology research. The project proposed herein will greatly enhance our capabilities in the area of *in situ* monitoring.

S.K. Sharma, A. Seki, S.M. Angel, and D.G. Garvis, Field testing of an optical fiber temperature sensor in a geothermal well, Geothermics **19**, 285-294 (1990).

C.M. Schoen, T.F. Cooney, and S.K. Sharma, Long fiber-optic remote Raman probe for detection and identification of weak scatterers, Appl. Optics (in press, 1992a).

C.M. Schoen, S.K. Sharma, A. Seki, and S.M. Angel, Near-infrared fiber optic temperature sensor, Proc. SPIE OE/Fibers '91, Sept. 3-6, 1991, Boston, Massachusetts (in press, 1992b).

BUDGET
Period: 7/1/92 - 6/30/93

A. Salaries	
1. S.K. Sharma (1 mo.)	$ 7,694
2. T.F. Cooney (3 mo.)	10,532
3. H. Olson (1 mo.)	5,885
4. Technical Specialist (3 mo.)	9,364
5. Graduate Assistant (12 mo. @ 50%)	15,558
Salaries sub-total	$ 49,013
B. Fringe Benefits	11,610
C. Equipment	
1. Optical fiber, armored, 3 km	35,000
2. Portable Spectrograph	10,000
3. Near-infrared Ge diode-array detector	40,000
4. Diode-pumped Nd:YAG CW laser	15,000
5. Diffraction gratings (2)	1,500
6. Data collection station	2,000
7. Portable optical bench, optics, & mounts	6,000
8. Motorized winch	2,500
9. Dielectric mirrors and filters	4,000
Equipment sub-total	$116,000
D. Travel	
1. Inter-island air fare (4 @ $100/trip)	400
2. Per diem (2 people, 10 days @ $85/day)	1,700
3. Truck rental (10 days @ $50/day)	500
E. Miscellaneous	
1. Communications, copying, shipping	800
2. Supplies	2,000
F. Indirect Costs (37.65% of MTDC, excluding C.)	24,865
TOTAL	$206,908