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A Fiber Optic Borehole Tool to Measure 3-D Fracture Deformations during Hydraulic Injection Tests*

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Objective: We propose to develop a new borehole tool to measure fracture deformations in three dimensions and at sampling rates of 10-50 Hz using fiber Bragg grating sensor technology. After laboratory testing and development, we will deploy the tool in a drift at the Homestake DUSEL to measure the deformation of natural fractures during hydraulic injection tests. The measurements will allow hydraulic fracture properties, such as transmissivity and storativity, to be related directly to mechanical aperture changes and will provide fracture stiffness data needed to understand the mechanical response of the Homestake rock mass to excavation and construction activity. The detailed fracture deformation data will improve understanding and models of fractured rock systems.

Experimental Approach: The experiment requires a short borehole that intersects a distinct fracture. The tool will be positioned to straddle the fracture and secured in place with conventional extensometer anchors. An inflatable packer will seal the borehole, and the fractured interval will be pressurized to open the fracture. The change in fracture aperture will cause a slight, relative offset of the anchors, which will be measured by a fiber Bragg grating system with a tunable laser light source. A fiber Bragg grating sensor consists of a doped optical fiber with an optically inscribed grating pattern. A change in strain or temperature shifts the center wavelength of the light reflected from the grating pattern, and a detection module records the shifts in peak reflectivity. The fiber optic sensors will be mounted on the sides of a flexible, square beam connecting the anchors. The beam deflection will be measured and used to solve for the relative displacement of the anchors in three dimensions. The tool will also contain a small pressure transducer to measure the fluid pressure and a temperature sensor to provide temperature compensation. The tool resembles a borehole extensometer developed and used successfully by Cappa et al. (2006) to measure fracture deformation in a single direction.

Anticipated Outcome: Fracture aperture changes will be analyzed over the entire fluid pressure cycle for each injection test. Fracture transmissivity and storativity will be calculated and related to mechanical aperture and fracture stiffness. Delineating these relationships will advance efforts to characterize the hydrological system in the Homestake DUSEL, and the fracture stiffness data will be valuable in modeling the mechanical response of the rock mass to excavation and construction activity.

Reference: Cappa, F., Y. Guglielmi, S. Gaffet, H. Lancon, and I. Lamarque (2006) Use of in situ fiber optic sensors to characterize highly heterogeneous elastic displacement fields in fractured rocks, *Int. J. Rock Mech. Min. Sci.,* **43**, 647-654.

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