Quantum Design

APPLICATION NOTE 1056-201

Fiberoptic Sample Holder (FOSH): Characteristics and Uses

The Fiberoptic Sample Holder (FOSH) for the MPMS allows the user to illuminate a sample with an external light source during magnetic measurements.

Optical Components

The FOSH consists of two main optical components: a 2-meter long flexible, multimode fiberoptic bundle and a solid fiberoptic rod. An SMA connector links the two components. The fiberoptic bundle and the fiberoptic rod have a diameter of 1.5 mm and a numerical aperture of approximately 0.2. The optical quality of the FOSH depends on the optical properties of the solid fiberoptic rod and the flexible fiberoptic bundle.

The solid fiberoptic rod is fixed inside the stainless-steel MPMS sample rod. The fiberoptic rod extends beyond the lower end of the MPMS sample rod into a sample holder that optically connects the flexible fiberoptic bundle to the sample.

The free end of the flexible fiberoptic bundle is bare and it can be connected to a light source using any type of connector that is appropriate to the light source, including an SMA connector (see Quantum Design Diagram 4056-001 in the *Sample Illumination System for the Magnetic Property Measurement System: Reference Manual)*.

Sample Holder

The sample-holder section of the FOSH consists of a spring-loaded slide assembly of nested quartz tubes. The sample-holder components are almost entirely quartz, which minimizes the magnetic background signal from the sample holder. Samples are mounted in a small quartz bucket that has a quartz lid to hold them in place. The bucket has an inner diameter of 1.6 mm and a depth of 1.6 mm. The small volume of the quartz bucket limits the size of the samples that can be inserted, so you may need to design a different sample holder, depending on the specific measurement being performed. The entire bucket assembly loads into the center of the quartz sample holder, where it rests on a second piece of solid fiberoptic rod. The quartz lid is held flush against the upper solid fiberoptic rod by a beryllium-copper spring, which is mounted on the bottom of the sample holder and pushes on the bottom of the bucket via the solid fiberoptic rod.

The quartz sample bucket contributes a magnetic moment that is the same as that of a void in a uniform piece of quartz. As quartz is diamagnetic, the signal of the bucket has the same sign as a paramagnetic sample. The magnitude of the bucket's signal is approximately 10^{-3} EMU at five tesla. The magnetic moment of the empty holder should be measured at all temperatures and fields of interest so that its magnetic moment can be subtracted from that of the sample. The Automated Background Subtraction (ABS) feature in the MPMS MultiVu Windows software can be used to automate the subtraction procedure.

Light Transmission Capability

Flexible Fiberoptic Bundle

The flexible fiberoptic bundle consists of many narrow, multimode optical fibers bundled together in a hexagonal, close-packed fashion (see Figure 1 in Appendix 1 of the *Sample Illumination System for the Magnetic Property Measurement System: Reference Manual*). The bundle arrangement has light-transmission capabilities similar to a solid rod but it is easier to connect to a light source.

The geometry of the optics and the spectral attenuation of the optical fibers both cause optical attenuation between the sample and the light source. Geometric attenuation occurs at the interface between the light source and the fiber bundle. As the bundle has spaces between each fiber, the actual active area is reduced by the ratio of the net fiber surface area versus the total bundle surface area. Furthermore, each of the flexible optical fibers consists of a core plus cladding and jacket. Thus, the actual active surface of each fiber is reduced by the ratio of the fiber core's surface area versus the total fiber's surface area.

Each flexible optical fiber has an inner-core diameter of 200 μm and a total fiber diameter of 245 μm. Once these two sources of geometric attenuation have been taken into account (attenuation due to the core-to-cladding ratio and attenuation due to the spaces between fibers), the total geometrical transmittance of the fiber bundle is approximately 61% (see Appendix 1 in the *Sample Illumination System for the Magnetic Property Measurement System: Reference Manual*).

Additional attenuation arises from light absorption in the optical fibers. The amount of attenuation depends on the fiber material, the frequency of the light source, and the length of the fiberoptic sample holder. As discussed in the *Sample Illumination System for the Magnetic Property Measurement System: Reference Manual*, the standard optical fiber for the FOSH is one that transmits near ultraviolet light with minimal attenuation. The fiber bundle has an operating wavelength of 180 nm to 1100 nm, while the standard solid fiberoptic rod has an operating wavelength of 180 nm to 700 nm. The FOSH are made of Fiberguide Industries' Superguide G UV-Vis fiber. For this fiber, the attenuation of a light source of a 300-nm wavelength is approximately 0.4 dB for a 2-m length (the length of the flexible fiber bundle that is supplied with the FOSH). Other fibers can be used in place of the Superguide G fiber. One such fiber is Fiberguide Industries' Anhydroguide G Vis-IR fiber, which is more suitable for transmitting near-infrared light.

Solid Fiberoptic Rod

A solid fiberoptic rod delivers the light from the flexible fiberoptic bundle to the sample. The rod is a large-diameter fiber made of the same material as the flexible bundle, and the active core has the same surface area as the flexible bundle (1.5-mm diameter). Thus, there is no geometric attenuation of light from the bundle to the rod. The solid fiberoptic rod is approximately 1.3-m long. The light attenuation from a rod composed of Superguide G is approximately 0.25-dB for a 300-nm light source. Thus, the total absorption within the bundle-rod combination is approximately 0.65 dB.

It should be noted that the geometric and absorptive attenuation values given above are estimations based on the specifications of the fiber and the geometric calculations for the bundle. Although these values are a good estimate of the capabilities of the FOSH unit, they do not include effects from possible errors such as the packing arrangement, a slight mismatching of the bundle to the rod, a slight difference in bundle and rod length, or the reflectivity of the light at each surface interface. They also do not include the effects of cooling on the parameters of the fiberoptic materials. If exact attenuation values are required, the user must determine them for his or her specific experimental setup.

Using the FOSH

Maximum Intensity of Illumination

The maximum intensity of light that can be used with the FOSH is determined by how much light the fiber can transmit before it is physically damaged (such as by heating). The flexible bundle is the more delicate optical component: it is most likely to be damaged at the input to the fiber bundle, where excessive light intensity could soften the epoxy that fills the gaps between the ends of the optical fibers and holds them together.

The need to keep the sample at a fixed temperature sets an upper limit to the light intensity. Above the upper limit, the heat energy of the light can cause the temperature of the sample to drift. Quantum Design cannot estimate the maximum intensity because it depends on experiment-specific parameters such as the material parameters of the sample (e.g., reflectivity, thermal conductivity, specific heat); the amount of material used; the cooling power of the environment at a specific temperature; and the type of light source. The large thermal mass of the sample holder may also introduce significant thermal lag time when measurements involve temperature sweeps.

Installation and Removal

The MPMS sample space should always be at room temperature when the FOSH is inserted or removed. Before installing or removing the FOSH, you must first disconnect the fiber bundle from the solid fiberoptic rod at the SMA connector. Otherwise, the sample rod could bend and damage the solid fiberoptic rod. During use of the FOSH, the fiberoptic bundle is mounted to a support bracket on the arm of the sample transport; the support bracket prevents the weight of the sample bundle from bending the top of the sample-support rod.

Compatibility

Aside from the exceptions noted below, the FOSH is fully compatible with all MPMS options and it is used in the same manner as the standard MPMS sample rod.

- The FOSH is not compatible with the Reciprocating Sample Option (RSO, option M130), which uses a different sample rod.

- Some of the sample-holder materials will not withstand high temperatures, so the FOSH cannot be used above 300 K or with the MPMS Oven option (M102).