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Design and Construction of an Optical TEM Specimen Holder

Joel Martis[1], Ze Zhang[2], Haokun Li[2], Arun Majumdar[1], Roy Kim[3] and Ann Marshall[2]

[1]Stanford University, Stanford, California, United States, [2]Stanford University, United States, [3]., United States

Optical imaging and spectroscopy provide rich information about the energy states of materials. However, their spatial resolution is limited by the wavelength of (visible) light to about 0.5 μm. Electron microscopy can achieve sub-angstrom resolution but provides limited spectral information with the exception of STEM EELS, which due to recent advances has become a powerful tool to probe the energy states of materials [1]. We recently proposed combining spectrally selective photoexcitation with HRTEM to achieve sub-nm scale optical imaging, a technique we called 'PAMELA' [2]. The experimental realization of PAMELA-TEM, however, requires introduction of light inside a TEM with a sufficiently high photon flux to produce a detectable signal.

Introduction of light can be done in two ways: through a port on the TEM (like the objective aperture), or through a TEM specimen holder. The former approach requires modification of an existing TEM, which can be expensive and potentially detrimental to the instrument. The latter is advantageous as a TEM holder can be inserted into any compatible TEM, and the holder can be modified without affecting the TEM itself. Because of this, we decided to fabricate a TEM specimen holder with light input capabilities.

Several researchers have designed and fabricated TEM holders with light input capabilities in the past [3-5]. These designs have experimented with both free-space optics based and fiber-optics based approaches. Free-space designs offer the possibility of high optical fluxes but require the light source to be rigidly connected to the holder thereby limiting the light sources that can be used. Fiber based designs have the flexibility of using a variety of light sources, but are typically limited in the smallest spot size they can achieve, leading to low optical fluxes. A combination of the two is ideal, as evinced by [5], where the authors used a fiber optic bundle in conjunction with a focusing lens to achieve a very small focal spot.

Here, we show the design and construction of an TEM specimen holder with a fiber optic feedthrough in conjunction with a microlens. The sample-side tip of the optical fiber is fitted with a micro-ball lens/reflector that can focus light onto a TEM grid. The other side is connectorized to allow for connection to standard fiber optic patchcords. The fiber optic feedthrough is detachable and allows for the optical fiber to be switched out depending on the desired wavelength range, optical flux, polarization and other parameters of interest. The optical fiber is held in place via a set of screws, which act like a micrometer stage and can be used to position the optical fiber and thereby focus laser light onto the desired area on the TEM grid.

In addition to the optics, several other design aspects of our TEM holder are discussed. Vacuum compatibility of the materials used in construction is an important consideration, as is the design of the vacuum feedthrough. Another consideration is the amenability of the specimen holder to modification. Bearing this in mind, our TEM holder is made to be modular with multiple detachable parts that can be switched out with newer/updated parts. We also discuss potential improvements for future designs such as more precise motion/kinematic control using piezo or electrostatic actuators and more options for photoexcitation like supporting a broader range of wavelengths, polarization control etc.

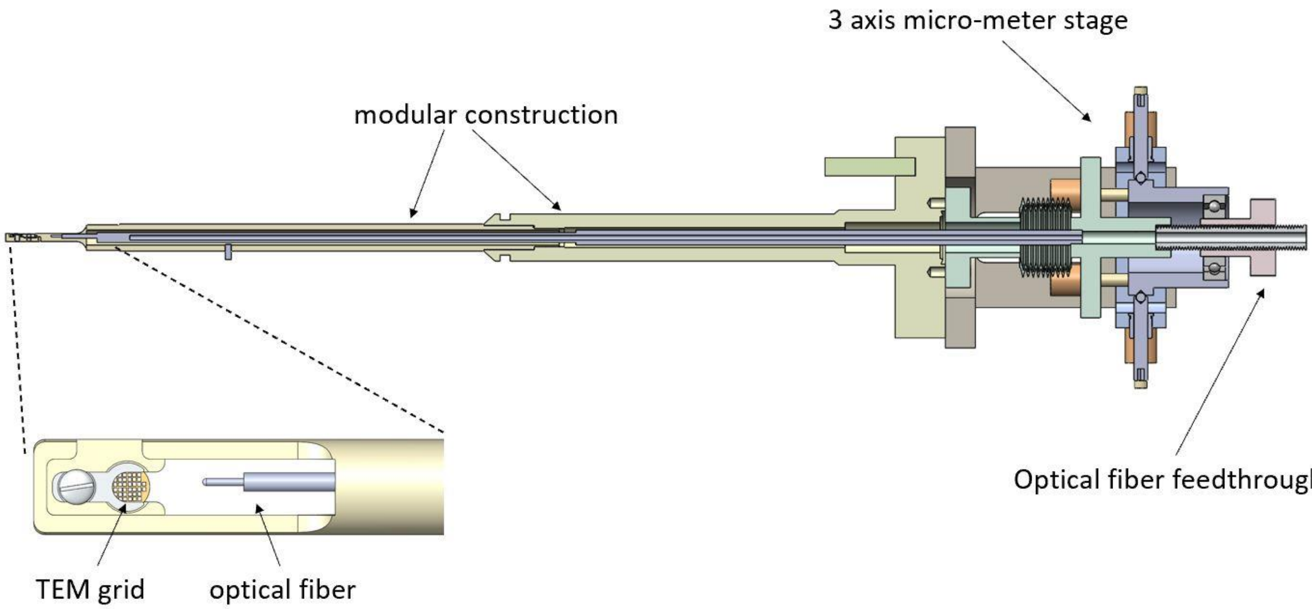

Figure 1. TEM holder design: CAD (cross section) of the optical TEM holder with a 3 axis micrometer stage at the rear end

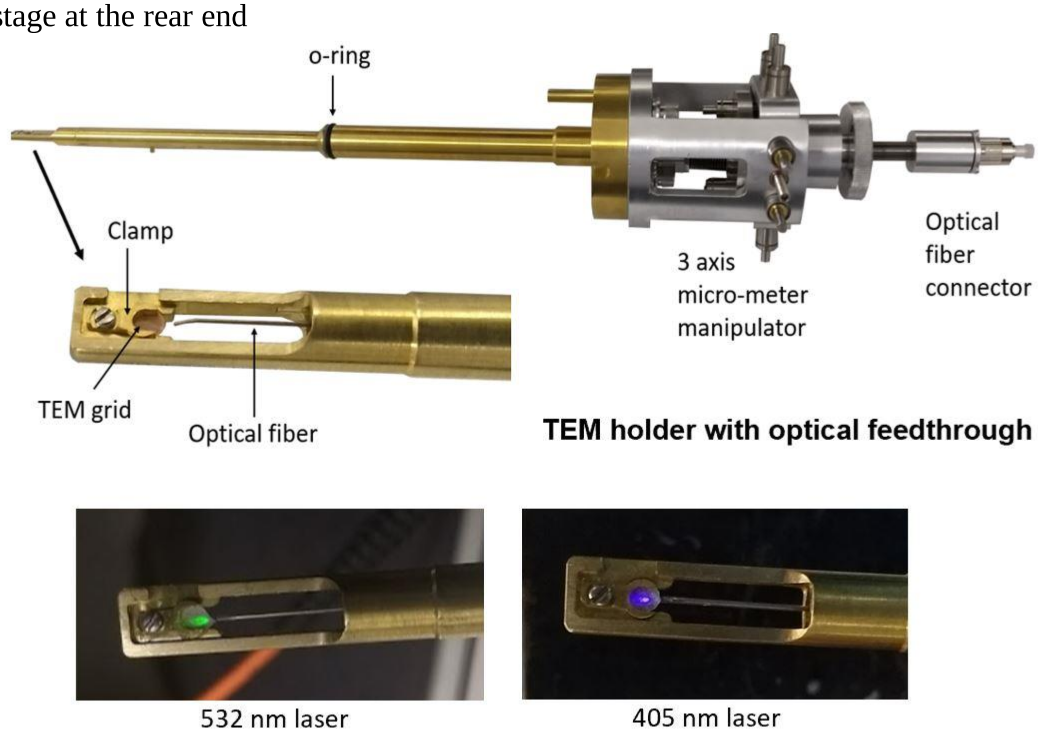

Figure 2. Top: Machined holder with micrometer stage and optical feedthrough; Bottom: Different lasers incident on the substrate.

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