Plasmonic Nanowire Continuum Light Source

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Abstract: Optically pumped gold nanowire, 330 nm in diameter imbedded into silicate optical fiber produces broadband, highly collimated radiation (in the range 470-900 nm) with divergence of less than 4 mrad.

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Recently demonstrations of lasing observed from gold resonators coupled with quantum dots and other gain media have given rise to the possibility of achieving nanoscale light sources, taking advantage of the inherent plasmonic properties of gold in a planar geometry [1,2]. Furthermore, gold nanowires have recently been integrated into optical fibers by pumping molten metal into the hollow channels of solid-core photonic crystal fibers (PCFs) [3,4], as well as through "stack and draw" techniques to achieve arrays of nanowires in glass matrices. Apart from extremely large aspect ratios these wires are free of impurities and the glass matrix also serves as a mechanical host to hold the nanowires in place. Such three-dimensional hybrid optical structures present a unique route to merge the fields of plasmonics and semiconductor optoelectronics with conventional fiber optics, thus far providing applications in sensing and sub-wavelength-scale imaging [5,6].

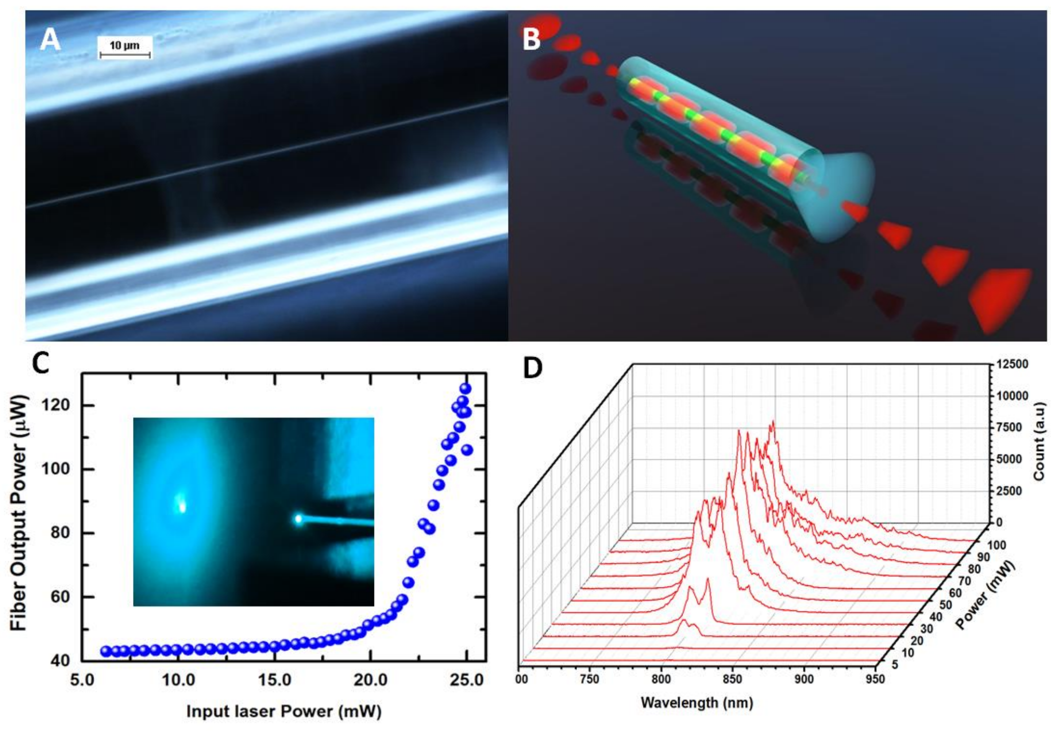

Figure 1: (A) Optical microscopy images of gold nanowires enclosed within glass fibers (B) Schematic of the gold nanowire fiber and output light. (C) Pump-collimated output characteristics of gold nanowire silicate hybrid fiber, showing a dramatic change in slope upon reaching a threshold (inset). Photograph of the output fiber light pumped with a 100 fs beam at 470 nm projected onto a screen, showing diverging light from the clad with a low divergence emission originating from the position of the nanowire. (D) Observed spectrum of emission from the fiber excited with a 800 nm, 100 fs pump with intensity ranging from 5 to 100 mW.

Here we present a novel fabrication method that takes advantage of planar nanofabrication techniques in conjunction with mass manufactured fiber drawing to realize gold nanowire of diameter 300 nm in a silicate optical fiber with an outer diameter of 100 µm (Fig. 1A) . This provides the platform for the experimental observation of directional beam emission from optical excitation with a 100 femtosecond beam across the UV to NIR (470 to 900 nm) wavelengths at a range of intensities. A clear distinction in threshold and spectral response is observed when pumping below, at, and above the absorption edge of the gold enclosed in the glass matrix.

The gold nanowire is excited by coupling the pump into the silicate enclosure, which facilitates multiple excitation of the nanowire through the length of the fiber as a result of repeated total internal reflection at the silicate/air interface. The observed light from the fiber shows light coupled within the silicate clad has been guided through the fiber and transmitted out with a large divergence angle (~16 mrads), while also showing a bright low divergence (3.84 mrads) emission originating from the position of the nanowire in the glass matrix (Fig.1B). We have determined the spatial coherence and pump-output dependence of the bright emission by mapping the far-field pattern of emitted light up to 40 cm away from the fiber tip (Fig. 1C), which shows a nonlinear dependence on input pump power that exhibits a threshold behavior with a dramatic change in slope.

In the spectral domain, an emission peak of gold nanowire was observed with a shift of ~20 nm from the pump wavelength, even at lower pump intensities. Furthermore, spectral broadening (around 150 nm spectral width) is observed at high excitation intensities (Fig. 1D).

The observed phenomenon both presents itself as a novel device in stark contrast to conventional commonly used technology and a complex yet exciting physical system at the intersection of plasmonics and optical fiber technology, that may offer a platform for the development of a new generation of plasmonic nanowire sources.

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