

Fiber facet reflection modified with a ZnO nanowire array

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Abstract: The modification of the end-face reflection for a single-mode fiber is observed and that is due to an array of ZnO nanowires with 40- to 50-nm diameter and 1-micron length deposited there.

The small uniform diameter ≤ 100 nm along with low absorption and large refractive index in the visible of wide-gap semiconductor nanowires have opened several avenues for pursuing sub-wavelength optical devices. Among others, ZnO continues to be of particular interest, not only for studies of fundamental solid-state physics but for application to optical waveguides. The practical implementation of ZnO nanowires requires a detailed understanding of coupling external light into the guiding modes of the nanowire whose diameter is much smaller than the corresponding vacuum wavelength. This report presents measurements of broadband light propagating through a single-mode optical silica fiber that has an end facet modified by a deposited array of ZnO nanowires.

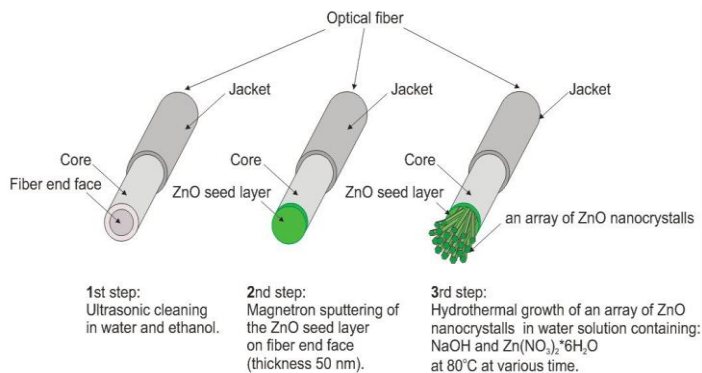


Figure 1 Technological procedure of a ZnO nanowire array formation on a fiber tip

In the solution, there is a concentration of 0.01 M of $\text{Zn}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ and 0.4 M of NaOH, and pH of this solution is equal to 13.2. The solution is kept for ten minutes a water bath heated to 80°C , and the end facet of the fiber is immersed into it afterwards and kept there for twenty minutes, correspondingly. The fiber with ZnO nanowires grown on its end facet, is cleaned in a deionized water and then air-dried. The length of the nanowire is equal 800 nm, diameter varies from 40 to 50 nm, and surface density is $5 \times 10^{10} \text{ cm}^{-2}$, correspondingly.

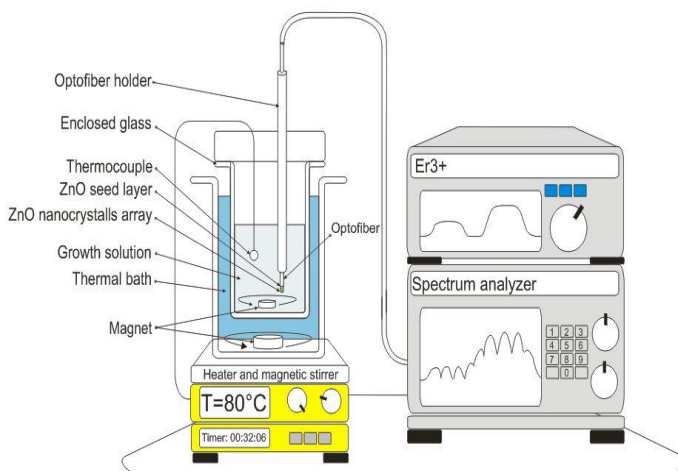


Figure 2 The experiment scheme to measure spectral features of the single-mode fiber with an array of ZnO nanowires on its cleaved facet

The procedure exploited to create an array of ZnO nanowires on a tip of a single-mode optical fiber is based on a standard technological procedure. In order to provide required level of the surface quality, the magneto-sputtering of 300-nm ZnO film is executed immediately after the fiber (SMF-28 Corning) cleaving. This film works as a catalyst for ZnO nanowires to grow and also provides proper adhesion and ordering for the structure to be created in the next step, where low-temperature chemical deposition is used to create an array of ZnO nanowires. In the solution, there is a concentration of 0.01 M of $\text{Zn}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ and 0.4 M of NaOH, and pH of this solution is equal to 13.2. The solution is kept for ten minutes a water bath heated to 80°C , and the end facet of the fiber is immersed into it afterwards and kept there for twenty minutes, correspondingly. The fiber with ZnO nanowires grown on its end facet, is cleaned in a deionized water and then air-dried. The length of the nanowire is equal 800 nm, diameter varies from 40 to 50 nm, and surface density is $5 \times 10^{10} \text{ cm}^{-2}$, correspondingly.

In the next step, the transmission and reflection spectra of the fiber that comprises a bundle of ZnO nanowires grown on its cleaved facets, are studied using experimental setup depicted in Fig. 1. The output of the Er^{3+} broadband source MPB EBS-7210 is launched into one piece of SMF-28 followed by a circulator and another length of the SMF-28 that has ZnO nanowires on its facet and is connected by means of an adapter to the optical spectrum analyzer AQ6370 by Yokogawa. The circulator is introduced into the set-up in order the reflection spectrum to be analyzed simultaneously.

The reflection spectra are measured for the clean cleaved facet, facet with a seed layer of ZnO on its cleaved surface, and with ZnO nanowires that are being grown on this cleaved facet, correspondingly, and the reflection spectrum is given in Figs. 3 and 4. It is readily seen a profound asymmetry in the reflection spectrum that does not

match the transmission one hence making a temptation to claim an observation of surface polaritons excited along the ZnO nanowires. Further basic measurements that are again the spectral measurement but with tilt and variable spacing introduced between the nanowires and collecting fiber confirm this assumption.

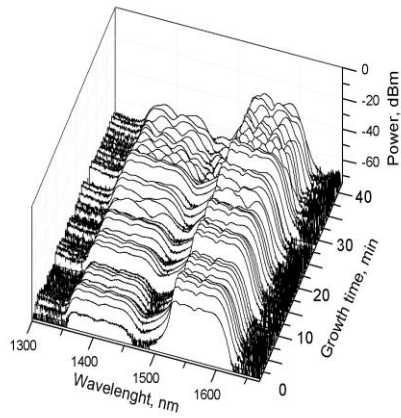


Figure 3 Kinetics of the spectrum of the broadband light reflected from the end facet with a seeding layer, where an array of ZnO nanowires is being grown.

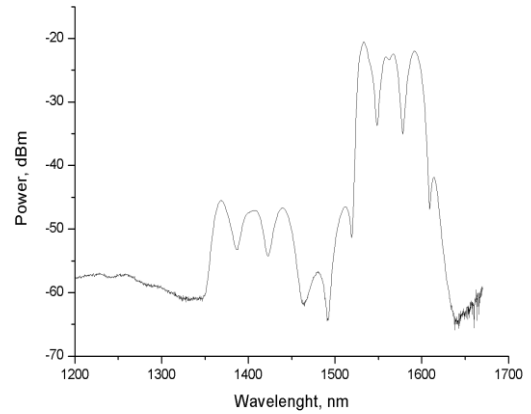


Figure 4 The near-IR spectrum of the single-mode fiber that is due to ZnO nanowires of 800 nm length and 40 nm diameter grown on its bare facet

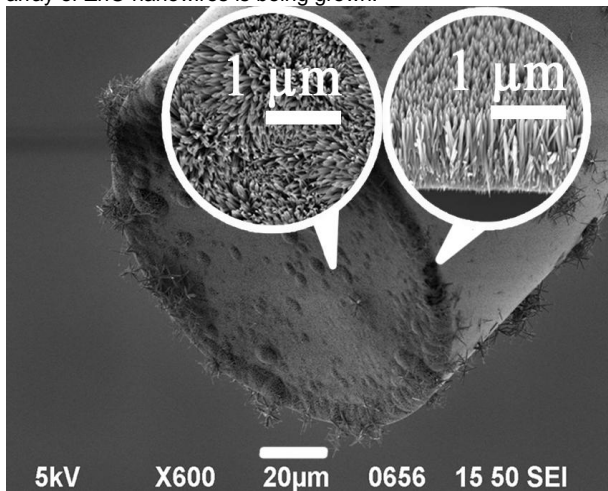


Figure 5 SEM image of the end facet of the single-mode optical fiber with ZnO nanowires grown.

In conclusion, measurements of the transmission and reflection spectra of the single-mode optical fiber that end facet is modified by a disordered (but yet controllable) array of ZnO nanowires, exhibit spectral asymmetry of the reflection due to the excitation of surface polaritons that propagate along the surface of the nanowire. The behavior reported here is of interest for the implementation of new sub-wavelength optical waveguides.