Gold-Nanoparticles Microfiber Saturable Absorber for Mode-Locked Erbium-doped Fiber Laser

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***Abstract*—We demonstrate the generation of 743 fs soliton pulses in erbium-doped fiber laser employing gold-nanoparticles saturable absorber. The mode-locking operation is achieved with gold-nanoparticles/polydimethyl-siloxane composite coated on a microfiber with 10 μm waist diameter, indicating the availability of fabricated saturable absorber for pulsed operation in 1.55 μm spectral range.**

***Index Terms*—Mode-locked, Nanomaterials, Ultrafast laser**

I. Introduction

Saturable absorber is a key component in producing optical modulation in passive mode-locked fiber laser designs. Research activities on saturable absorbers (SAs) are still evolving due to increasing interest in new material development. Recently, graphene, topological insulators, transition metal dichalcogenides and black phosphorus have been investigated for their optical saturable absorption properties [1], [2]. Likewise, gold nanoparticles (Au-NPs) were reported to have saturable absorption effects owing to the collective electron oscillation in the conduction band at the particle surface [3]. Based on this property, Au-NPs in the form of nanorods have been utilized in generation of picosecond [4] and femtosecond [5], [6] mode-locked pulse generation by sandwiching the Au-NPs between fiber ferrules and depositing the Au-NPs on microfiber, respectively.

For the microfiber SA, the Au nanorod deposition was based on the optical trapping effect. However, this technique is susceptible to environmental effects due to the absence of protective layers. To mitigate this issue, the Au-NPs can be embedded in a polymer matrix before deposition on the microfiber. In this paper, Au-NPs in polydimethyl-siloxane (PDMS) composite is utilized as the coating layer of a microfiber with 10 μm waist diameter.

II. Methodology

For this research work, an adiabatic microfiber of 60.5 mm total length with waist diameter of 10 μm is fabricated using Vytran GPX-3400 workstation. The average diameter of the prepared Au-NPs is between 40 and 60 nm as depicted by the field effect scanning electron (FESEM) image in Figure 1(a). The centrifuged Au-NPs solution of 1 g is mixed with 3 g of PDMS. The mixture is stirred and heated at 80 °C for 2 hours. The solvent is evaporated during the heating process, leaving a composite of Au-NPs/PDMS. The prepared Au-NPs/PDMS composite is then drop-casted on the tapered region of the microfiber to complete the fabrication of the SA. A 633 nm light source is injected into the Au-NPs/PDMS-SA as presented in Figure 1(b), where the scattered red light denotes the interaction between the evanescent field around the tapered region and the Au-NPs/PDMS composite. The Au-NPs/PDMS-SA shows a transmission loss of less than 2.8 dB with 0.25 dB variation as shown in Figure 1(c).

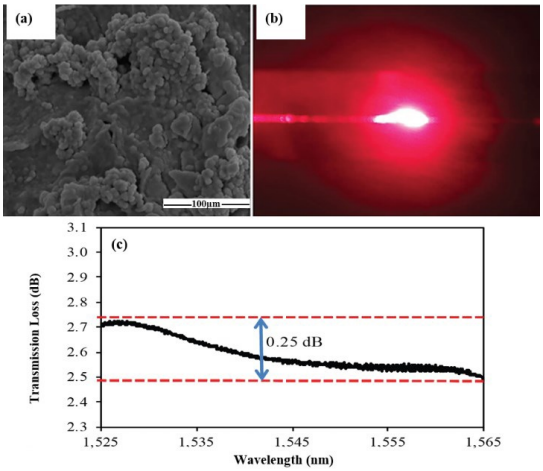

Fig. 1. (a) FESEM image of Au-NPs, (b) evanescent field interaction with Au-NPs/PDMS composite on the microfiber, and (c) transmission loss of Au NPs/PDMS-SA

III. Results and Discussion

Figure 2 depicts the optical spectrum of mode-locked EDFL with Au-NPs/PDMS-SA. The radiation started off as spontaneous emission which transitioned to continuous wave (CW)

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