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Pulsed-laser-ablated gold-nanoparticles saturable absorber for mode-locked erbium-doped fiber lasers

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ABSTRACT

We demonstrate the optical performance of passively mode-locked pulses in erbium-doped fiber laser incorporating gold-nanoparticles (Au-NPs) as a saturable absorber (SA). Au-NPs of diameters between 5 to 15 nm were synthesized using the pulsed laser ablation method and blended with polydimethylsiloxane polymer. The resulting nanocomposite was deposited on the tapered region of a microfiber with a spin-coating method. The proposed Au-NPs SA recorded a modulation depth of 0.4% and low saturation intensity of 0.1 MW/cm^2 leading to stable mode-locking operation in the erbium-doped fiber laser cavity at a low threshold pump power of about 45.6 mW. A mode-locked pulse train with a duration of 933 fs, pulse repetition rate of 6.25 MHz, and peak-to-pedestal extinction ratio of 54.1 dB was achieved at a pump power of 168.1 mW. The obtained results demonstrate that the spherical Au-NPs synthesized by pulsed laser ablation is a feasible material for SA fabrication, validating its saturable absorption properties in a 1.55 μm wavelength region.

1. Introduction

The ultrafast fiber laser's ability to generate incredibly short pulses with durations of picosecond or less makes it valuable in an ultrafine high precision application, such as material processing and medical application [1]. Current commercial ultrafast laser implements semiconductor saturable absorber mirror, which was first introduced by Ursula Keller [2]. Despite its huge success, its operation wavelength is limited to a specific wavelength and the fabrication process using molecular-beam epitaxy is also complicated [1]. Since the first employment of graphene as a saturable absorber (SA), the exploration of two-dimensional materials within a similar group has continued with the emergence of transition metal dichalcogenides (TMDs) and topological insulators (TIs) [1]. TMD has a high damage threshold while TI exhibits superior modulation depth (MD) [3]. By constructing a van der Waals heterostructure within these materials, an outstanding pulse performance with complementary properties can be realized [3,4].

Black phosphorus (BP) has a graphite-like structure with controllable optical bandgap energy [5] which has been widely explored for ultrafast laser generation [6]. Other than that, a newly explored SA using perovskite nanosheets has gained attention in ultrafast photonics too, due to its high MD and capability to operate steadily in a normal dispersion regime with no sign of pulse splitting [7]. However, this material contains lead, a highly toxic element that has high solubility in water [7]. Additionally, for the case of BP and perovskite, proper encapsulation is required to preserve the material from the decomposition of its chemical constituents under an ambient environment. A hybrid mode-locking method is frequently practiced whereby the phase-locking is initiated by the combined effect of saturable absorption of SA material and intracavity nonlinear polarization rotation (NPR) effect. The ultrashort pulse width of 246 fs [8] and 67 fs [9] were attained via tungsten disulfide-based tapered fiber SA assisted by the NPR effect. Apart from that, a special pulse with an inverted feature in the time domain, dubbed as dark soliton was also observed in Ref. [10].

In recent decades, metal nanoparticles like gold nanoparticles (Au-NPs) have been employed in chemical and biological sensors [11], microscopic applications [12], solar cells [13] and optical devices [14]. Metallic nanostructure is a three-dimensional material which optical

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