Monroy Lafuente, L., Esteban, O., Monroy, E., González Herráez, M. & Naranjo, F.B. 2021, “High energy ultrafast all-fiber laser based on InN-GRIN saturable absorber”, in OSA Advanced Photonics Congress, 26-30 Jul 2021, OSA Technical Digest, art. no. NoW3C.4, pp. 1-2.

Available at http://dx.doi.org/10.1364/NOMA.2021.NoW3C.4

High energy ultrafast all-fiber laser based on InN-GRIN saturable absorber

L. Monroy[1], Ó. Esteban[1], E. Monroy[2], M. González-Herráez[1], F.B. Naranjo[1]
[1]*GRIFO, Dept. Electrónica (EPS) Universidad de Alcalá, Campus Universitario Alcalá de Henares 28871, Madrid, Spain*
[2]*Univ. Grenoble-Alpes, CEA, Grenoble INP, IRIG, PHELIQS, 17 av. des Martyrs 38000, Grenoble, France*
Author e-mail address: laura.monroy@uah.es

Abstract: A simple, solid, cost-effective GRIN-to-fiber coupling system has been developed by incorporating an InN-based SESAM in a polarization independent ring-cavity EDFL. The assembly delivers stable high-power (70 kW) ultrashort pulses (90 fs) at the laser output. © 2021 The Author(s)

1. Introduction

In recent years, there has been an increasing demand for optical fiber lasers, since they can deliver high quality ultra-short pulses with high peak intensities [1]. Among them, passively mode-locked lasers relying on semiconductor saturable absorbers (SESAM) have been extensively studied for a wide variety of applications in the fields of industrial production, biomedical treatments or telecommunications, owing to their relatively low cost and simple implementation [2,3]. However, saturable absorbers (SAs) have some limitations, including low achievable energy and peak power (up to a few kW), which have hampered the commercial deployment of these technologies.

In our current study, we draw on recently-introduced InN-based SAs [4], which have demonstrated superior properties in terms, for instance, of thermal and chemical stability, polarization insensitivity and radiation hardness. Here, an InN SESAM was successfully employed in a passively mode-locked fiber laser at 1.56 µm, demonstrating highly stable sub-250 fs pulse generation and up to 40 kW of peak power without the need for post-amplification stages within the laser cavity [5].

The introduction of a saturable absorber in an all-fiber laser cavity is a convenient and simple way to achieve ultrafast pulses. In this sense, the SA must be deposited or transferred on the optical fiber in order to prevent reflection losses. Saturable absorbers are generally deposited by spin-coating on highly-reflective mirrors or directly integrated on the fiber facet. However, to improve its stability under high power operation, the SA can also be deposited on the sidewalls of the optical fiber (e.g. tapered fiber, side-polished fiber or cladding-etched fiber). This scheme has enabled to increase the operation power before damage, but nonlinear polarization rotation effects may appear within the laser cavity. Therefore, in order to develop high-power ultrafast fiber lasers, new coupling methods must be investigated.

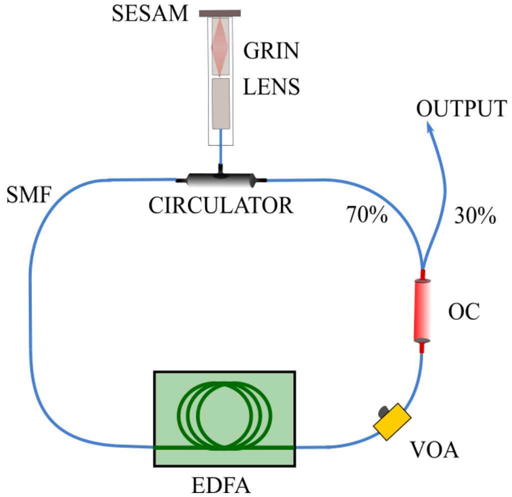

Fig. 1 Fiber integration of the saturable absorber by material deposition on the fiber end with a GRIN-rod lens in an all-fiber Er-doped laser emitting at 1.56 µm.

In this work we propose a GRIN lens as the coupling device directly placed between the fiber end and the saturable absorber. The InN-based material is fixed to the lens face with an UV-optical adhesive, and then cemented to the optical fiber facet, as shown in Fig.1. Since this scheme has no optical path in air, the reflection losses within the laser cavity are minimized. This results in pulses with high peak power and optical energy, proving the excellent reliability of the system. Thus, an efficient and ultra-simple ultrafast fiber laser assembly is developed in the telecommunication region.

2. Results

The experimental setup consists of a ring-fiber type cavity with an InN SESAM as the passive element. The saturable absorber is based on an active InN layer grown by molecular beam epitaxy on a 10-µm-thick GaN-on-sapphire template. A 300 nm-thick Al-layer is deposited on the InN film for SESAM configuration. The saturable absorber demonstrates polarization independence due to its wurtzite structure, therefore no polarization control is needed inside the laser assembly. The cavity consists of 25 m of SMF and an EDFA with 16 m of EDF and 24 dBm of optical gain, following the scheme in Fig. 1. The net cavity dispersion coefficient is -0.21 ps^2, thus working in the anomalous regime.

To demonstrate the stability of the optical system, the autocorrelation trace and the spectrum are depicted in Fig.2. The output pulse is centered at 1576 nm with a FWHM of 42 nm and a temporal width of 92 fs (the black line represents a Gaussian fit). The average power, peak power and optical energy were 30 mW, 65.2 kW, and 6 nJ respectively. From these results, the TBP was 0.46, denoting a slight chirp of the output pulse train within the laser cavity.

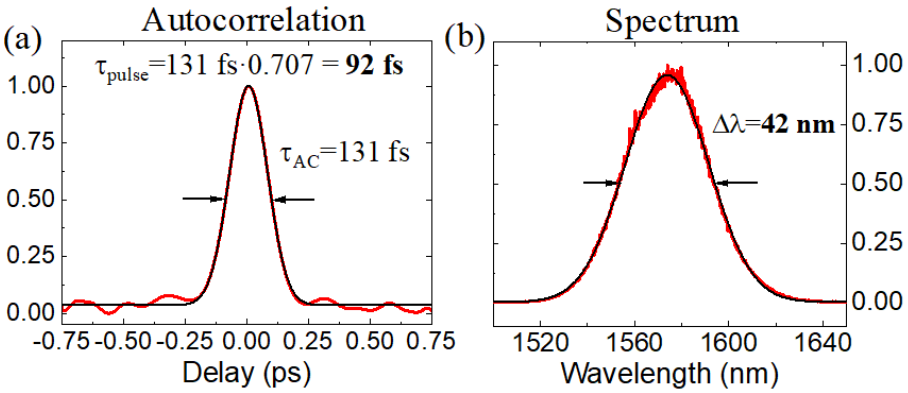

Fig. 2 Optical characterization of the output pulses: (a) autocorrelation trace, and (b) optical spectrum.

In conclusion, we present a new optical coupling technology based on GRIN-to fiber SA. The optimized all-fiber laser cavity results in a shorter pulse duration (92 fs) compared to free-space cavity schemes reported in previous works (134 fs) [6], and among the shortest pulses achieved by 2D material-based saturable absorbers. Also, the peak power and pulse energy have increased by two times (65 kW and 6 nJ) with respect to the best results obtained with free space coupling to the SA (28 kW and 5.4 nJ). Therefore, InN-based SAs coupled to a GRIN lens and implemented in a fiber laser assembly have demonstrated unique properties in the generation of ultra-stable pulse trains with ultrashort pulse durations.

3. References

[1] M. N. Zervas and C. A. Codemard, “High Power Fiber Lasers: A Review,” IEEE J. Sel. Top. Quantum Electron **20**, 219-241 (2014).
[2] U. Keller, K. J. Weingarten, and F. X. Kartner, “Semiconductor saturable absorber mirrors (SESAM’s) for femtosecond to nanosecond pulse generation in solid-state lasers,” IEEE J. Sel. Top. Quantum Electron. **2**, 435–453 (1996).
[3] S. Taccheo, “Fiber lasers for medical diagnostics and treatments: state of the art, challenges and future perspectives,” in Optical Fibers and Sensors for Medical Diagnostics and Treatment Applications XVII (Proc. SPIE 10058, 2017), 1-6.
[4] M. Jimenez-Rodriguez et al., Opt. Express **25**(5), 5366 (2017).
[5] M. Jiménez-Rodríguez et al., "Ultrafast Fiber Laser Using InN as Saturable Absorber Mirror," J. Lightwave Technol. **36**, 2175-2182 (2018).
[6] L. Monroy, et al., “High-Quality, InN-Based, Saturable Absorbers for Ultrafast Laser Development,” Appl. Sci. **10**, 7832 (2020).