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► To cite this version:

Frédéric Delahaye, Foued Amrani, Benoît Debord, Frédéric Gérôme, Fetah Benabid. Ultra-violet optical amplifier based on plasma-core PCF. Conference on Laser and Electro-Optics /Europe (CLEO/Europe-EQEC 2019), Jun 2019, OSA, Jun 2019, Munich, Germany. Paper CJ-3.1. hal-02330742

HAL Id: hal-02330742

<https://hal.science/hal-02330742>

Submitted on 23 Nov 2020

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Ultra-violet optical amplifier based on plasma-core PCF

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Optical amplifiers are an important key element in modern physics. For example, in optical communication, in order to transmit signal over long distance, they are inserted to compensate optical signal attenuation due to fiber loss. For system laser they are used as active gain medium. Today, optical amplifiers can be divided into two classes: doped fiber and solid-state amplifiers [1]. However, these conventional amplifiers are mainly limited to the visible and near infrared spectral range. This limitation is particularly acute in the ultra-violet (UV) range because of the lack of suitable materials for UV emission and optical guidance. Conversely, gas-filled hollow-core photonic crystal fiber (HCPCF) has successfully been extended to ionized gases by generating and micro-confining stable plasma using non-intrusive [2] and compact microwave surface-wave excitation configuration [3]. It was proven that with this new plasma-core PCF (PCPCF), one could emit radiation over a large spectrum including several lines in the UV and DUV [4].

In this paper, we report to our knowledge on the first DUV/UV amplifier using an “all plasma-core PCF” architecture whereby radiation line at 315 nm was generated in one PCPCF and amplified with a maximum gain of ~14 dB by a second PCPCF for a microwave pump of 17 W.

Fig.1 (a) shows the two stages experimental set-up. The first stage consists of a PCPCF used to generate the signal. The latter is filtered from the plasma radiation spectrum by a diffractive grating before sending to the second stage of the set-up comprised with a second PCPCF. Both PCPCF are excited with a microwave generator (the details of this technique is detailed in [2]). The two PCPCF are made with a 20 cm long 19-cell hollow-core defect Kagome PCF filled with a ternary gas mixture of argon, nitrogen and oxygen (Ar/N₂/O₂). Fig. 1(b-1) shows the typical emitted spectrum in the range of 250-425 nm when the above PCPCF is excited with 17 W microwave power. Fig. 1(b-2) and 1(b-3) summarizes the evolution of the spectrum emitted from the amplifying PCPCF when a radiation line at 315 nm of 35 nW from the first PCPCF is coupled in. The grey-filled curves represent the spectrum in the absence of 315 nm seed line, and the blue-curves represent the spectrum with the presence of the seed for two values of the amplifying PCPCF microwave excitation power. For a microwave power of 15 W, we readily see a strong amplification of the 315 nm line and suppression of the rest of spectrum lines. The gain evolve with the amplifying PCPCF microwave excitation power for a seed line at 315 nm. By gradually increasing the microwave power, the gain increases linearly with the microwave power indicating that the population inversion is sufficient to provide gain. Within this microwave range the gain increases almost linearly to a maximum of ~14 dB. Current effort is to increase the microwave power to determine the saturation level.

In conclusion, a new type of DUV/UV optical amplifier is proposed. An experimental demonstration of ~14 dB amplification of radiations at 315 nm is achieved. The results indicate that the PCPCF technology is an excellent candidate for reproducing the outstanding results of near infrared lasers in the “untamed” DUV/UV spectral range.

Fig. 1 (a) Experimental set-up. (b) Emitted DUV/UV spectra from the amplifying PCPCF in the case of no seed line (grey filled curves), and in the presence of 35 nW 315 nm seed line (blue curves) for the case of 17 W (Fig. 1(b-2)) and 15 W (Fig. 1(b-3)) of microwave excitation power.

This research is funded through grants ANR-DGA Maturation Plasma-PMC, PIA-4F and la région Nouvelle Aquitaine.

[1] D. Zimmermann *et al.*, “Amplifiers for the masses: EDFA, EDWA, and SOA amplifiers for metro and access applications”, Journal of Lightwave Technology, 2004

[2] B. Debord *et al.*, “Generation and confinement of microwave gas-plasma in photonic dielectric microstructure”, Optic Express, 2013

[3] F. Vial *et al.*, “Generation of surface-wave microwave microplasmas in hollow-core photonic crystal fiber based on a split-ring resonator” Optics Letters, 2016

[4] F. Amrani *et al.*, “Gas mixture for deep-UV plasma emission in a hollow-core photonic crystal fiber”, Optics Letters, 2017