# Active mode-locking and CW regimes operating simultaneously in an Erbium doped fiber laser

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**Abstract:** We demonstrated an Erbium-doped fiber laser operating simultaneously in two distinct regimes, CW and active mode-locking at 1.8 GHz with pulses of 38 ps. The lasers wavelengths can be tuned in both regimes.
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## 1. Introduction

Multiwavelengths lasers are very attractive for many applications as optical communications and instrumentation, even they can be work in mode-locking regimes[1] or in multiples regimes[2],[3], as we propose here. The simplest setup for multiwavelengths lasers is obtained when an output from CW laser is coupled to a router or a diffraction grating, where each one of channels has an optical or semiconductor amplifier or a combination of them [4], [5], these kind of lasers are tunable. They have an advantage about accuracy space between channels, but insert multiples amplifiers may increase the cost of system. So, it is common use NALM [1], however this kind of lasers do not allows insert simultaneous and different rates as the arrayed waveguide gratings, AWG [6]. AWGs are usually made by silica or derivatives, with waveguides showing little difference between light paths neighbors, doing an interference pattern. They are easily integrated, offer low channel interference and are passive elements that do not need increase of pump energy of laser. Other good advantage is that AWGs are made as ITU recommendations.

In this work we demonstrated for the first time to our knowledge a laser that operates simultaneously in two regimes. We integrated two AWGs into a ring what allows the two regimes of operation in different channels simultaneously. The first one is an active mode-locking regime and the other one is a CW.

## 2. Setup

The laser setup, showed in Fig.1 is a fiber ring configuration with 1m Erbium-doped fiber long as gain medium. One WDM device that contains an isolator that force backward propagation signal, one polarization control and an output beam splitter of 16% of signal. Each AWG has approximately 3 m of single mode fiber, SMF, they are commercially WDMs devices, with 40 channels separated by 100 GHz or 0.8 nm and full width at half maximum, FWHM, of 0.4 nm. When paired as show in the picture they show a FWHM of ~ 0.32 nm. The cavity is 10.3 m length without AWGs. With gratings it goes to 16.4 m long. The average input current at the pump diode laser is fixed in 200 mA, while the output power in16% port is from 1.0 to 1.2 mW.

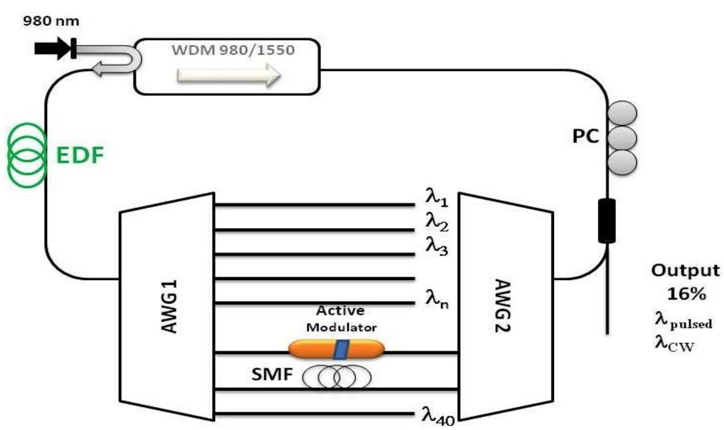


Fig. 1 Setup of the dual operation regimes EDFL with two Arrayed Waveguide Gratings. An active modulator and a single mode-fiber were introduced between the two gratings in order to generate mode-locking and CW operation regimes simultaneous.

## 3. Results

Fig. 2 a) shows the output spectrum of the laser with two distinct wavelengths. The black curve corresponds to the CW laser operating at 1557.4 nm with a FWHM of 0.04 nm and the red curve the active mode locking at 1559 nm with a FWHM of 0.12 nm. The spectra line widths show clearly that the bandwidth of the active mode locking is broader than the laser with CW operation, which is an indication that the two regimes are working simultaneously. Fig. 2 b) shows a train of pulses with duration of 42 ps at 1.8 GHz representing the temporal profile of the laser output, where the CW operation adds a small DC signal. This train of pulses is due to the active modulator operating at 7.5 GHz. Although the RF frequency is set to 7.5 GHz at the modulator, a good mode locking is obtained at a lower frequency of 1.8 GHz that better adjust the gain between the two lasers. By forcing the operation at 7.5 GHz, the laser line width reduces to 0.04 nm, which is actually the resolution of the optical spectral analyzer.

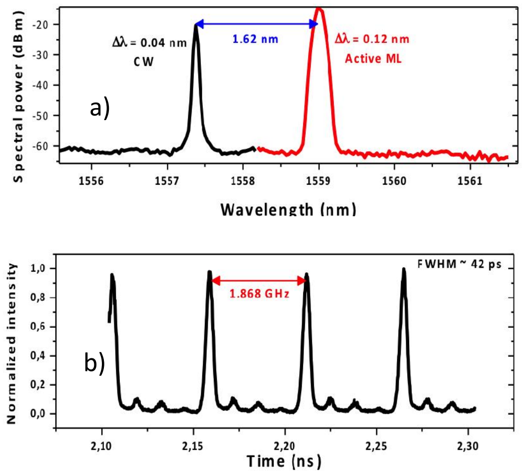


Fig. 2 a) Output spectrum of the laser with two distinct profiles representing the two regimes of operation. b) Train of pulses at 1.8 GHz due to the active modulation at 7.5 GHz

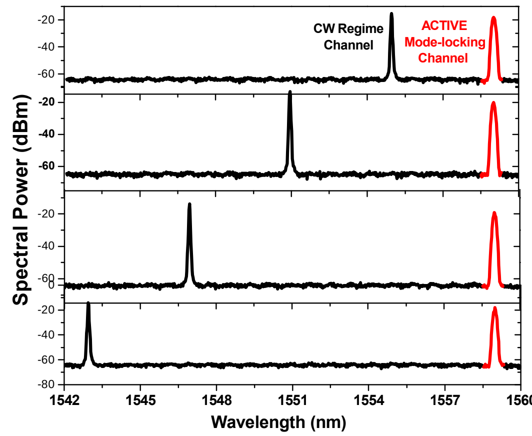


Fig. 3 Tunability of CW laser over the Erbium gain bandwidth. The mode-locked laser channel can also be tuned.

Fig. 3 shows that the CW laser can be tuned over the Erbium gain bandwidth. No variation on the mode-locking such as pulse duration or stability was observed during the tuning of the CW lasers. The same tuning can be done also with the active mode-locked laser. In fact it demonstrates that this laser (or these lasers) has a great flexibility in terms of tunability and adjustability to specific wavelength and application.

## 4. Conclusion

This work presented an Erbium-doped fiber laser operating with two distinct regimes simultaneously. It was possible by the insertion of two AWGs into de laser cavity. The CW laser was tuned over the Erbium gain bandwidth while the active mode-locking operated at 1.8 GHz with pulse duration of 38 ps. This laser supports many others channels operating in other regimes simultaneously.

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