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# Wavelength Stabilization of Extended-Cavity Tapered Lasers with Volume Bragg Gratings

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**Abstract:** We describe the strong wavelength-stabilization of high-brightness extended-cavity lasers based on 808-nm and 976-nm tapered amplifiers by use of volume Bragg gratings. Single-frequency operation has been obtained in a robust and simple design.

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## 1. Introduction

Narrow spectrum, high-brightness semiconductor lasers emitting in the near infrared are of great interest for a wide range of applications, from direct pumping of rare-earth solid-state lasers to non-linear frequency conversion to the visible for medicine or spectroscopy. The most promising design proposed for high brightness emission in the 1-W power range is the tapered laser diode [1]. It consists in a single-mode ridge acting as a spatial filter and a large tapered amplifier section. Several realizations have been described in the literature, demonstrating output powers as high as 4 W in a nearly diffraction-limited beam [2-5]. However the large emission spectrum of these devices remains a strong limitation for demanding applications. A well-known, efficient way to control the laser spectrum is to use the tapered device as the gain medium in an extended-cavity with a spectrally selective component. Usually it consists of a diffraction grating in a Littrow configuration, which allows both tunability and spectral selectivity [6,7]

We proposed a new and simpler design for the numerous applications in which the emission wavelength is *a priori* known. The spectrally selective element is a volume reflection grating, which forces the laser emission to the Bragg wavelength whereas the output power and beam properties are imposed by the tapered amplifier structure.

## 2. Description of the external cavity

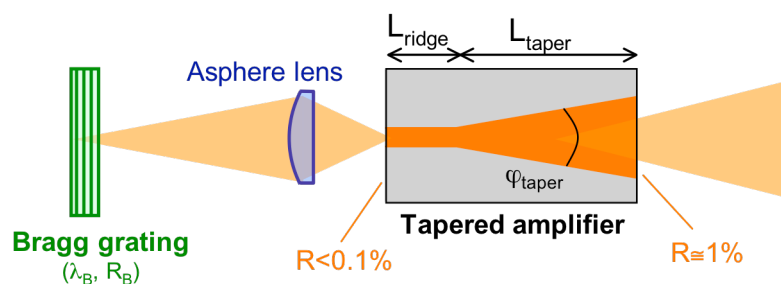


Figure 1 : Design of the extended-cavity tapered laser.

Our external cavity is very simple: on the first hand, the volume Bragg grating is realized in a photosensitive glass, which allows direct writing of periodic structures under UV illumination to make filters with the desired properties. Here we used commercial Bragg gratings, with reflectivity in the range 10% - 40 % and a reflection bandwidth of 0.5 nm or less [8]. On the second hand the laser medium is a tapered amplifier with an antireflection coating on the single-mode ridge side ( $R < 0.1\%$ ), and a low reflection coating on the tapered side ( $R \sim 1\%$ ). On the ridge side the emission is focused into the Bragg grating with a high-NA asphere lens. Let's note that the focalization of the beam inside the grating results in a stronger control of the emitted wavelength and a lower sensitivity to cavity misalignments than in the case where the beam is collimated.

We have used this cavity scheme (Fig. 1) with different high-brightness tapered amplifiers: the first ones were single quantum well InGaAs/AlGaAs devices designed to operate at 980 nm, with a

filtering ridge section length of 500  $\mu\text{m}$ , a taper section length of 2.5 mm and a taper angle of 6° [4]. The second ones were based on the well-established GaAsP/AlGaAs layer structure designed at 808 nm, with a 500  $\mu\text{m}$ -long ridge and a 3.5 mm-long 4°-angled tapered section [5]. For comparison tapered lasers with the same layer and transverse structure but a HR coating on the rear facet have been realized, demonstrating high beam quality for output powers up to 3 W.

### 3. Experimental characterization of the laser emission

With both 976 nm and 808 nm amplifiers without optical feedback, no laser emission could be observed but only amplified spontaneous emission covering a large spectrum. In external cavity an output power of typically 1 W was emitted from the large tapered output for an operating current of about 4 A. This output power was mainly limited by the performances of the semiconductor amplifiers, indeed we have measured similar characteristics with our volume gratings or with a broadband high reflectivity mirror. A strong laser emission at the Bragg wavelength was observed with our different gratings for any reflectivity in the range 10% to 40%. As shown in fig. 2, the side-mode suppression is 40 dB, and the laser line is locked at the Bragg wavelength whatever the amplifier operating current or temperature, with a FWHM linewidth lower than 80 pm (OSA-limited). The single longitudinal mode operation of the 976.0 nm extended-cavity tapered laser was controlled with a scanning Fabry-Perot interferometer with a free spectral range of 8 GHz. A true single-frequency operation was obtained though some mode-hopping appeared if the operating conditions were changed. Very similar results have been demonstrated with the 808-nm tapered sources and a Bragg grating characterized by  $\lambda_B = 807.3$  nm and  $R_B = 40\%$ .

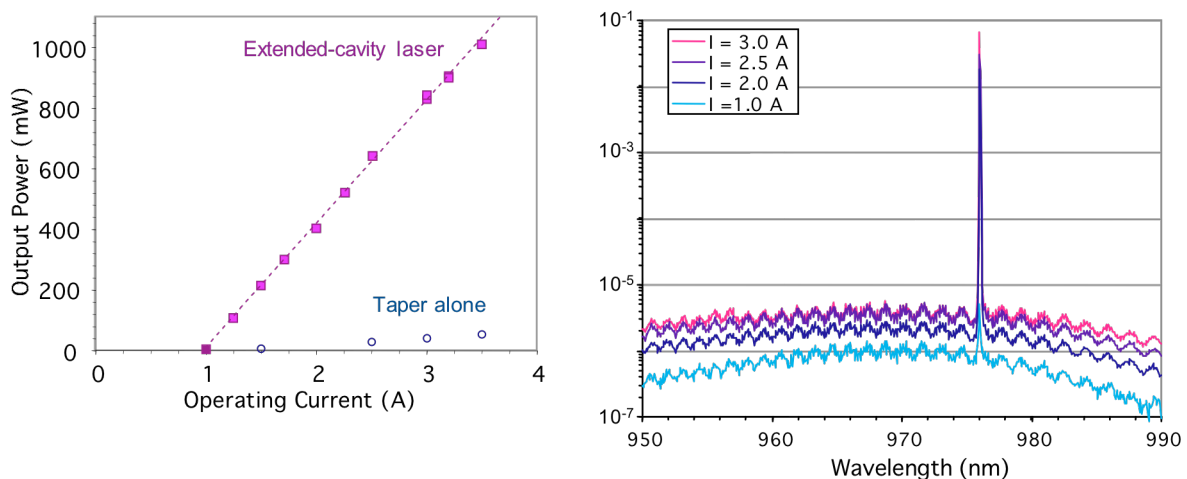


Figure 2 : (Right) Laser spectrum of the tapered source in extended-cavity, for different amplifier currents ; the Bragg wavelength is at 976.0 nm, and the reflection coefficient of the grating at this wavelength is 10%. (Left) Output powers for the tapered amplifier alone (ASE) and in extended-cavity laser operation ( $T = 25^\circ\text{C}$ ).

### 4. Conclusion

We have demonstrated an output power of 1 W from high-brightness tapered amplifiers in a new compact and robust external cavity operating at the fixed wavelength imposed by a volume Bragg grating. Such laser sources are adapted for second harmonic generation in non-linear crystals towards the visible spectrum (488 nm, 405 nm e.g.), thanks to their narrow linewidth and good beam quality. We are now looking forward improving the output power of these sources with improved amplifiers.

### 4. References

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