Numerical modelling of high-power self-organizing external cavity lasers

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Introduction

In this paper, we present a self-consistent model of a high-power self-adapting laser cavity. It consists of a photorefractive crystal model, which relies on a phenomenological plane wave approach[1]. The laser amplifier model uses a spectral approach[2]. The dependence of the gain on the wavelength has been pre-calculated using a dynamic gain model[3] and included in the simulations via a look-up table.

Fig. 1 shows the structure of the self-organizing external cavity laser. This device consists of a high-power tapered amplifier and a photorefractive crystal situated between a high reflectivity mirror and the rear facet of the tapered amplifier.

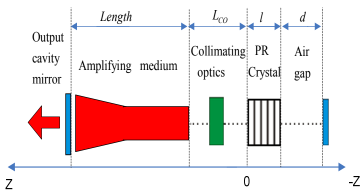

Fig.1: High-power self-organizing external cavity laser.

Simulation Parameters

Symbol	Value	Unit	Definition
l	0.3	cm	PR Crystal Length
d	3.0	cm	Air Gap Length
Length	0.7	cm	Amplifier Length
G	5.0	cm^{-1}	PR Gain Coefficient
n	2.4		PR Refractive Index
r	$0.9^{1/2}$		Reflectivity of Output Mirror

Assumptions and limitations of the model

1. Only the main cavity mode writes the PR grating.
2. The longitudinal mode beating frequency is too large to form a dynamic grating in the PR crystal. Hence, there is no direct coupling between longitudinal cavity modes by the PR grating.
3. Only the first harmonic of the grating written by the light intensity of the fundamental mode is included. All higher harmonics are neglected.
4. The PR crystal model is based on a 1D plane wave approximation.
5. The model calculates the field distributions of the possible cavity modes, but does not allow determination of their temporal evolution or stability.

Simulation and Results

Step 1: Calculate the resonant wavelength of the main mode of the cavity.

This is done by repeatedly running the single wavelength 2D LD model and taking the advantage of the fact that no phase shift is introduced by the PR grating for the main mode. Hence, the wavelength is obtained using 1D model without PR crystal. From this calculation, we obtain the main mode at 972.573nm using a base current of 0.55A.

Step 2: Calculate the resonant wavelengths for the side modes.

This is done by calculating the phase shift introduced by the PR grating and performing a 1D analysis of the cavity in order to calculate the resonant wavelengths of the other longitudinal modes.

Step 3: Calculate the characteristics of the self-organizing tapered laser cavity.

This step is performed using the 2D LD spectral model and the values of the PR crystal reflectivity calculated for the calculated resonant wavelengths.

The reflectivity of the resonant modes with the PR grating and the 'possible modes' without the PR grating are compared in Fig. 2.

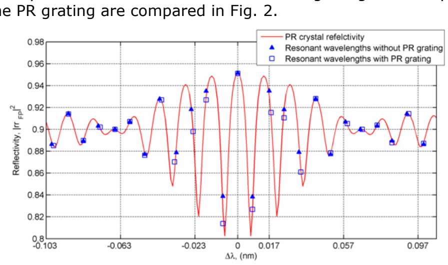

Fig. 2: Comparison of the reflectivity of the resonant modes and possible modes.

The calculated results indicate that at steady state a single longitudinal mode is supported by the cavity (see Fig. 3).

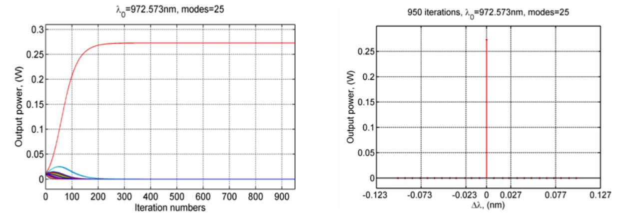

Fig. 3: The iteration procedure of the resonant modes (left); The converged output power for every mode (right).

The results also show that the near-field and far-field profiles are nearly Gaussian (see Fig. 4).

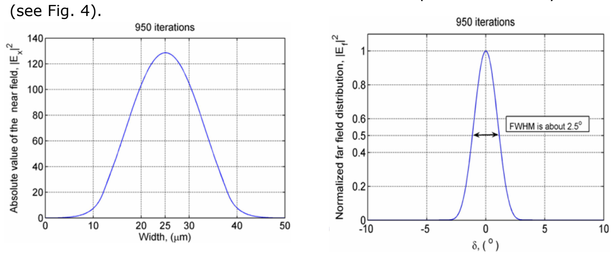

Fig. 4: The distribution of the near-field (left) and the far-field (right).

The 2D distributions of the photon density and carrier density within the tapered amplifier section show that at a high output power a spatial hole is formed (see Fig. 5).

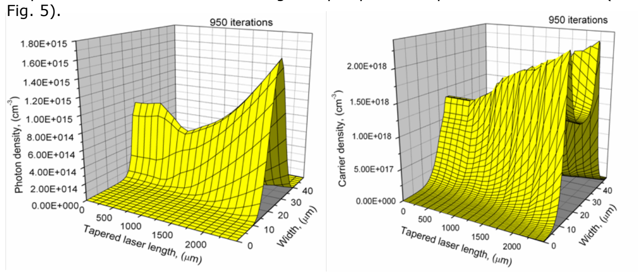

Fig. 5: The 2D photon density distribution of the main mode (left) and the carrier density (right).

Fig. 6 shows the calculated light-current characteristics. The calculated threshold current is 0.15A, while the slope efficiency equals 0.70W/A. The results obtained also show that at a bias current of 2.3A the resonant wavelength shifts to 972.581nm. We believe that this results is from the electrical over-pumping effect.

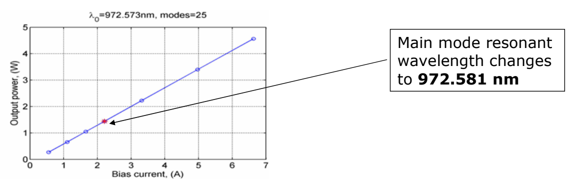

Fig. 6: The light-current characteristics of the main mode.

Conclusions

A two-dimensional spectral model of a self-organizing external cavity laser with a photorefractive crystal in the external coupling loop was developed.

The model combines a 2D spectral laser diode model and a 1D adaptive Fabry-Perot filter PR crystal model, which is based on the plane wave approximation of the wave diffraction.

We observed a wavelength shift, which was attributed to the electrical over-pumping effect.

References

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3. P.J. Bream, S. Sujecki, and E.C. Larkins, IEE Proceedings-Optoelectronics, Vol. 153, No. 6, pp. 299-307, 2006.