New design of continuously tunable single mode laser

Margarita Deneva, Marin Nenchev

Technical University-Sofia, Branch Plovdiv
and IE-Bulgarian Academy of Sciences
72 blvd. Tsarigradsko Chaussee, 1784 Sofia, Bulgaria,
e-mail: mdeneva@yahoo.com

ABSTRACT

We describe a novel design of a laser spectral-selective resonator that permits to obtain in a very simple manner a continuously tunable single-longitudinal mode laser generation. The exact matching of the frequency of the selection and this one of the selected mode during the tuning is obtained using a combination of a convenient prismatic tuner and an Interference Wedge. Due to the shown simultaneous and linear variation of the length of the resonator and the frequency of the IW transmission, the tuning is by simple translation only of the prism.

The Single longitudinal Mode lasers with a Continuously Tunability of the selected mode (SMCT-lasers) are very important quantum-electronics devices [1]. Such lasers assure a minimal line-width of the laser emitted spectrum - of order of few hundreds or few thousand Hz for the fundamental frequency of order of 10^{14} Hz. In combination with the continuous tuning of the selected frequency they present important tools for the high-resolution spectroscopy, for the isotope separation and lidar systems, for biomedical investigations, for metrology e.t.a. The development of simple solutions of such devices is of essential interest and under continuous actuality in the literature. The main interest presents the solutions where the tuning is obtained by variation of only one resonator or selector parameter and in simplest manner – i.e. by simple mechanical translation or rotation. The essential problem is that when the selected frequency is tuned, due to the fixed frequency of the resonator longitudinal modes, the tuning is by "mode jumping" when the frequency jumps from mode to mode during the variation of the frequency of the selection. In the literature are proposed and are in practical use three systems for such tuning with a simple variation of the position of one tuning element (mechanically, electrically) [2]. In this tuning system a variation of one parameter leads to variation in convenient manner of the some other resonator parameter that results of synchronous and equal variation of both frequencies – this one of the tuning and this one of the selected mode.

In this work we propose and show the reality for realization of a new system of discussed type. The schematic diagram of the resonator proposed is shown in Fig.1. It consists of the output mirror M_o , the low-resolution selector LRS of the spectral region of operation (e.g. en appropriate Interference Wedge IW [3]- IW_{LRS}), a laser

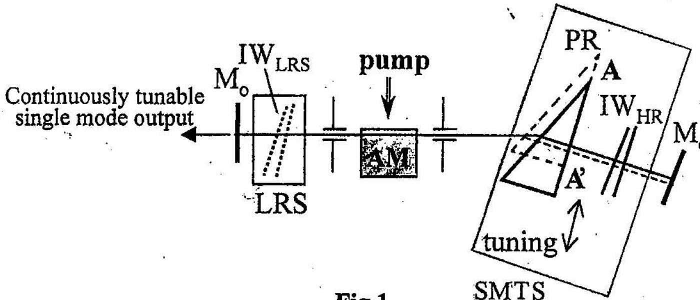

Fig.1

active medium AM with amplification in wide spectral range (e.g. –dye, semiconductor, Yb^{3+} :YAG), the single mode tuning system SMTS and the end mirror Me. The SMTS proposed is shown more detailed in Fig.2. It consists of an appropriate rectangular prism PR with refraction index of the composed material *n* and an high resolution Interference Wedge IW_{HR} .Both working surfaces of the prism are anti-reflection coated. The laser axis , that is fixed by the diaphragms D_1 and D_2 falls to the prism hypotenuse at an angle that assure to be perpendicular to the prism front plane AA'. The last consist with the plane of the hypotenuse an angle θ. The Interference Wedge IW_{HR} is disposed after the prism PR and its plane (of the front mirror of IW_{HR}) consists an angle of few angular minutes with the front plane AA'of the PR. It can be shown from the consideration of Fig.2 that if the prism PR is translated at a distance ΔX in direction AA' as it is shown in Fig.2, after the prism the axis is translated at distance ΔY and the optical length of the laser axis is changed by ΔL where ΔY and ΔL are given by the relations:

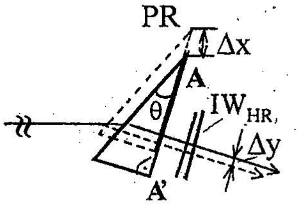

Fig.2

$$\Delta L = \Delta X \cdot F(\theta, n)$$

$$\Delta Y = \Delta X \cdot G(\theta, n)$$

where

$$G(\theta, n) = \sin^2\theta \left(n\sqrt{\frac{1-\sin^2\theta}{1-n^2\sin^2\theta}} - 1 \right)$$

$$F(\theta, n) = tg\theta \left\{ \sqrt{\frac{1-\sin^2\theta}{1-n^2\sin^2\theta}} - n\left[1 + G(\theta, n)\right] \right\}$$

The changes of the selected mode frequency and the frequency of the selection for the translation of PR at ΔX are given respectively by:(in the wavelength expressions with L_0 (6 cm) - the resonator optical length and λ_0- the wavelength for ΔX = 0):

$$\Delta\lambda_m = \lambda_o . L_0^{-1}\, \Delta X . F(\theta, n) \qquad \text{(for the selected mode)}$$

$$\Delta\lambda_S = \Delta\lambda_I .\, \Delta S^{-1}\, \Delta X .\, G(\theta, n) \qquad \text{(for the selection)}$$

To obtain continuos single mode tuning the condition is $\Delta\lambda_m = \Delta\lambda_S$ which leads to the following relation between the parameters of the PR and IW_{HR}:

$$\Delta\lambda_I .\, \Delta S^{-1} . G(\theta, n) = \lambda_o . L_0^{-1} . F(\theta, n) \qquad (1)$$

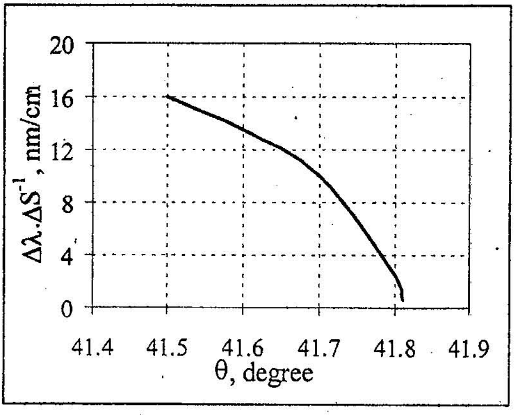

Fig.3

Here, $\Delta\lambda_I$ is the spectral distance between two spectral resonanses of the interference wedge IW_{HR} and ΔS is the linear distance between two spatial resonances. The calculated by (1) dependence of $(\Delta\lambda_I . \Delta S^{-1})$ as a function of the PR angie θ and for n = 1.5 (glass prism) is given in Fig.3. From the figure it can be seen that for the very realistic in practice values of θ and $\Delta\lambda_I .\, \Delta S^{-1}$ a continuous tuning of the selected single mode can be obtained.

In conclusion we have proposed a novel and simple laser resonator for continuos tuning of the selected single longitudinal mode. We have shown that such resonator is very realistic for practical realization. An essential advantage is that only single translation is needed for the tuning (in a difference of the complicated grating rotation in the traditional schemes).The tuning element is a low cost glass prism.

This work is supported partially by the Grant of Technical University-Sofia, branch Plovdiv, 2002.

References:

1.Demtreder W., Laser spectroscopy. Basic conception and technique, Springer, 2000

2. Nenchev M.N. and Meyer I.H., Opt. Let, 1982, Vol.7, pp.199-201

3. Neveux M., Nenchev M.N., Barbe R., Keller J-C., IEEE J. Quant.Electron., 1995, Vol.31, pp. 1253-1260