DUAL-WAVELENGTH LASER: IMPROVMENT OF THE TUNING CHARACTERISTICS

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ABSTRACT

We present two simple and effective approaches for widening of the tuning region of the two-wavelength generation in two-channel laser cavity. The first is based on the use of combination of interference wedge and linear neutral filter and the second - on the use of active mirror. This widening is combined with near equal intensities in both emissions. The use of the active mirror assures a real simultaneous two-wavelength operation. We consider a Dye laser.

INTRODUCTION

The simultaneous operation of Dye and Ti:Al_2O_3 lasers at two independently tunable wavelengths is of interest for many practical applications, such as differential absorption measurement, including DIAL lidar atmospheric pollutants monitoring, isotope separation system, in non-linear optics e.c.t. The lasers of such type are intensively developed and frequently discussed in the literature [1,2]. Recently, we have reported an improved high efficient two-wavelength Dye and Ti:Al_2O_3 lasers with a passive self-injection [2].

An essential problem, that arises the two- wavelength operation of the lasers with a homogeneously broadened active medium (e.g. Dye, Ti:Al_2O_3), is the narrow range of simultaneous generation at the two wavelengths. This limitation is due to the well-known strong wave competition effect in this type of active media [1]. It is of importance the development of effective solutions of this problem.

In this work we present two simple and effective approaches for widening of the tuning region of the two-wavelength generation. This widening is combined with near equal intensities in both emissions. We provide a comparative study of the proposed techniques by computer simulation. The experimental test for the correcnest of the simulation is also given.

BASIC SCHEMES OF THE TWO-WAVELENGTH LASER.

We consider, as a basic scheme, a two-wavelength laser with two-channel cavity configuration (Fig.1), introduced earlier by us [1-3]. In this scheme, an interference wedge [1] IW_1 is used as a selective element in one of the channels and simultaneously as a low-losses channel-coupling element. The wedge is with a linewidth of the transmission ~ 1nm FWHM and transmission maxima T_{IW1} = 0,85 at spectral distance of ~ 36 nm. The first channel consists of the output mirror M_1, interference wedge IW_1, as a selector, and the full reflecting end mirror M_3. The mirror M_1, IW_1 as an intermediate reflector, IW_2 as a selector, and the deaf mirror M_3, form the second channel. The tuning of the first wavelength λ_1 is performed by translation of the IW_1 in its plane (a sandwich type of interference wedge is considered [1]). The tuning of the second wavelength λ_2 is performed by translation of IW_2. The laser active medium AM is introduced in the common part of the channels. To transform the described conventional type selection two-wavelength scheme in high-efficient passive self-injection type scheme [1] (PSIL laser), a partially transmissive mirror M_2 is introduced between AM and IW_1. In the investigation we use values of the laser parameters, given in the picture. The active medium is ethanol solution of Rh6G (5.10^{-4} mol/l). The pumping is by pulses from frequency doubled Nd:YAG laser (0,53 μm harmonic, pulse length 15 ns FWHM trapezium approximation of the shape with rise front of 7ns, plato - 3,5ns, and fall front - 16ns; pulse energy 0,25 mJ).

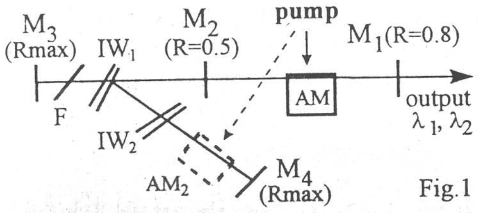


Fig.1

RATE EQUATION SYSTEM AND WAVELENGTH COMPETITION.

The action of the described two-wavelength laser is moddeled by adapting of the rate equation System (1) [2], where N is the invertion population per unity volume, $N_t=3.10^{17}\text{cm}^{-3}$ is the total number of the dye molecules per unity volume, $B_i=\sigma_{21}^i l\, c_o / V_a L'$ (i =1, 2, f), where σ_{21}^i is the emission cross-section for the corresponding wavelength i=1, 2 and the background emission at the gain maximum ($1,85.10^{-16}$ cm^2) [2]. Here, l=1 cm and V_a= $2,8.10^{-4}$ cm^3 are the length and the working volume of the active medium, respectively; L'=5cm is the optical length of the cavity and c_o is the light velocity. The terms $k_i.(N/\Delta f)\approx 6,43.10^{-16}$ [2] give the rate of

$$\frac{dN}{dt}=Wp(t).N_t-N.\sum_i B_i.q_i-\frac{N}{\tau}$$

$$\frac{dq_1}{dt}=B_1.q_1.N.V_a-\frac{q_1}{\tau_{c1}}+k_1.\frac{N}{\Delta f}$$

$$\frac{dq_2}{dt}=B_2.q_2.N.V_a-\frac{q_2}{\tau_{c2}}+k_2.\frac{N}{\Delta f}$$

$$\frac{dq_f}{dt}=B_f.q_f.N.V_a-\frac{q_f}{\tau_{cf}}+k_f.\frac{N}{\Delta f}$$

System (1)

photons produced in the laser mode volume by the spontaneous emission; τ=3 ns and $\tau_{ci} = L'c_o/\gamma$ are respectively the lifetime of the upper laser level and of a photon in the cavity, where $\gamma = -\frac{1}{2}\left[lnR_1R^e + 2\cdot ln(1-T_i)\right]$ describes losses in the cavity. Here, $R^e = R_3 . T_{IW_1}^2$ for the conventional cavity (R_2=0, R_3= $R_4 \approx$ 0,99). For the PSIL laser $R^e = \left|\left(\sqrt{R_2} + T_{IW_1}\cdot\sqrt{R_3}\right)/\left(1 + T_{IW_1}\cdot\sqrt{R_2R_3}\right)\right|^2$. The system is solved numerically using Runge-Kutta4 method.

The calculated dependencies of the output energy for λ_1 (E_{out1}) and for λ_2 (E_{out2}), when the λ_1 is fixed at the gain maximum and λ_2 is tuned, are presented in Fig.2. The strong competition between the two generations and respectively the limitation of the tuning region for simultaneous near equal intensities generation is

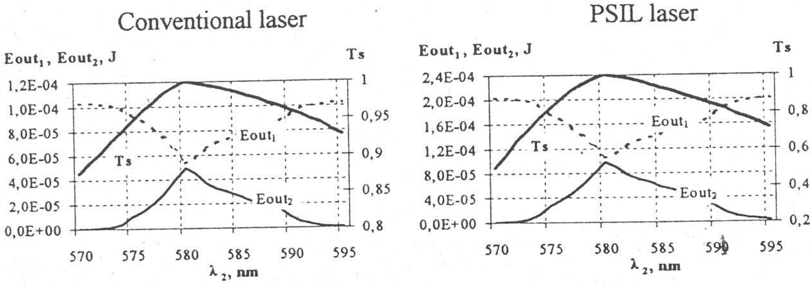


Fig.2

evident. The calculated curves are in good qualitative agreement with the experimental data and particularly with the given by us [1] experimental curves for two-wavelength tuning region for homogeneous broadened active medium. The needed additional losses (1-T_s) in the first channel (for λ_1), as a function of λ_2 for producing near equal intensities for the emissions at both wavelength can be also determinated from Fig.2. In this Figure the calculated wavelength dependence of the needed transmitivity T_s of the neutral density filter in the first channel is given.

PRINSIPLE OF THE PROPOSED APPROACHES FOR TUNING REGION WIDENING.

As a solution of the problem we introduce:

i. A technique of synchronously corrected losses in one of the channels with the tuning using a combined system based on appropriate transmissive filter and interference wedge. We employ the fact that the tuning with the interference wedge is linear with its translation [4] and the needed additional losses for correction in the first channel are also near linear (see the computing in Fig.2). Thus, with single translation of an incorporated in a common support interference wedge and appropriate linear transmission dependence filter we can obtain the needed effects.

ii. The second system is based on the use of an active-reflection mirror [3] in the channels. The active mirror consists of end-reflecting mirror in the channel of the tunable wavelength λ_2 and with the same active medium AM_2 as AM, pumped by part (b%) of the pump radiation (Fig.1 with dashed lines). When λ_2 is tuned, we vary the pump of the second active medium in manner to increase the gain in the second channel to compensate the decreasing of cross-section $\sigma(\lambda_2)$. The action of this scheme is described by the System (2), where the notations are the same as in the System (1). The added equation for dN_2/dt concerns the inversion population N_2 in the additional active medium AM_2. The calculated dependencies of the needed pump for the second active medium as a function of the wavelength to maintain the approximately equal generated energy for λ_1 and λ_2 are given in Fig.3. In the calculation λ_1 in the first channel is stopped at the gain maximum. In practice, the pumping of the second medium can

$$\frac{dN_1}{dt} = Wp_1(t).N_t^{(1)} - N_1.\sum_i B_i.qi - \frac{N_1}{\tau}$$

$$\frac{dN_2}{dt} = Wp_2(t).N_t^{(2)} - B^{(2)}.q_2.N_2 - \frac{N_2}{\tau}$$

$$\frac{dq_1}{dt} = B_1.q_1.N_1.V_a - \frac{q_1}{\tau_{c_1}} + k_1.\frac{N}{\Delta f}$$

$$\frac{dq_2}{dt} = B_2.q_2.N_1.V_a + B^{(2)}.q_2.N_2.V_a^{(2)} - \frac{q_2}{\tau_{c2}} + k_2.\frac{N}{\Delta f}$$

$$\frac{dq_f}{dt} = B_f.q_f.N_1.V_a - \frac{q_f}{\tau_{cf}} + k_f.\frac{N}{\Delta f}$$

System (2)

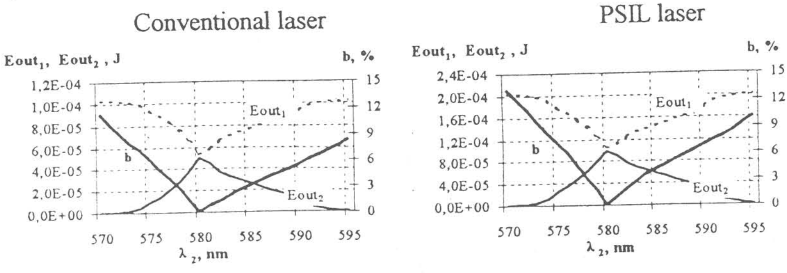
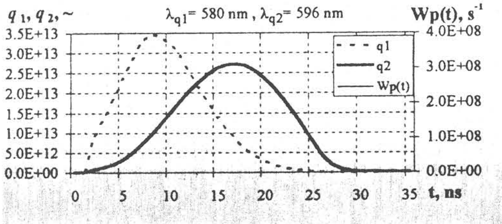


Fig.3

be achieved by polarization division of the initial pump power between AM and AM_2 and using a rotated polarizing active element before the separated Glan prism. Very important result is that for the introduced by us technique with compensating active mirror temporally both emissions are completely overlapped also when λ_2 is tuned far at the gain maximum (~ 16 nm); λ_1 is stopped at the gain maximum. This is not the case for compensation with the variable filter. In Fig.4 are presented the typical computed curves for the PSIL laser. In the bottom figure is also presented the temporal shape of the pumping. The same type of dependencies as is shown in Fig.4, are obtained for the conventional laser (R_2=0). The described two-channel scheme with the active mirror presents another very important opportunity. By choosing of suitable losses in both channel and temporally division of the pump pulse, as it is described in Ref.[5], and appropriate delayed pumping of the AM_2 by respect of the pumping of AM we can stopped the generation at λ_1 in a desired moment. Thus, if the dye laser operates at "spiking" regime [6] we can select in λ_1-channel only the first subnanosecond "spike".

For PSIL laser with compensation by filter



Fof PSIL laser with compensation by active mirror

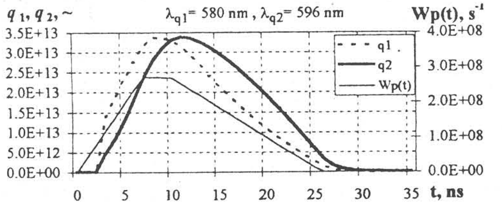


Fig.4

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