

SINGLE-FREQUENCY DYE LASER WITH FREQUENCY TUNING CONTROLLED BY A PROGRAM

V.A. Kapitanov, G.E. Kulikov, and V.I. Tyryshkin

*Institute of Atmospheric Optics,
Siberian Branch of the Russian Academy of Sciences, Tomsk
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A single-frequency automatically tunable cw dye laser automatically tuned to a fixed frequency (with an error of 500 MHz) has been developed. A single-frequency regime of lasing is achieved by the use of an automatic frequency tuning system. Frequency is measured by the Spektron-IV device. CAMAC instrumentation and a computer are used to control a lasing frequency. The laser can be used as part of laser opto-acoustic spectrometers and spectrophotometers.

Laser spectroscopy, both opto-acoustic and spectrophotometric, using multipass cells and recording of a derivative, which are employed for examination of the spectral characteristics of atmospheric gases and gaseous pollutants, make it possible to obtain simultaneously high spectral resolution and high sensitivity in a wide spectral range from the visible to the IR.¹⁻³ This is achieved by the use of narrow-band tunable lasers such as dye, Ti-doped sapphire, CO, CO₂ lasers, etc.⁴⁻⁹

The majority of modern tunable lasers, along with the advantages including narrow lasing linewidth and wide (several tens of nanometers) spectral range of operation, have principal disadvantages connected with narrow range of continuous linear tuning (a few tens of GHz) and hence necessity of frequency tuning to its initial value and its measuring, as well as with complexity of synchronous control over several selectors.

In this paper, the problems of development and design of a cw tunable dye laser automatically tuned to a fixed frequency, which can be employed as part of laser opto-acoustic spectrometer and spectrophotometer, are discussed.

Block diagram of the laser is shown in Fig. 1. The laser consists of three main parts:

1. Cw dye laser. Design of this laser and its parameters were described in Refs. 8 and 9 in detail. Elements providing single-frequency regime of lasing and tuning are as follows: the Lyot filter, fine Fabry-Perot etalon, and selective reflector.

2. System of automatic lasing frequency tuning to maximum reflectivity of the selective reflector. Such a system provides stable single-mode lasing and simplifies laser tuning.

3. System of automatic lasing frequency control. All the elements, used to select modes of a resonator, are equipped with electromechanical actuators. The Lyot filter is actuated by a stepping motor that allows

frequency tuning over the spectral range of lasing of the R6G dye from 580 to 610 nm. Tuning step is 210 GHz if higher-resolution selectors are not tuned (lasing frequency is tuned in jumps to fine etalon modes). Tuning step is 24 GHz if the fine etalon and the selective reflector are tuned (in this case, the step size is determined by the stepping motor - Lyot filter system). A direct-current motor serves as an electromechanical actuator of the fine Fabry-Perot etalon. It allows continuous rotation of the etalon through $\pm 2.5^\circ$. The voltage is applied to the actuator from a decimal digital-to-analog converter (DAC) through a linearizing amplifier. Tuning range is 210 GHz (one region of free dispersion of the etalon). Tuning step is 7.5 GHz if other selectors are not tuned (lasing jumps between the modes of the selective reflector) and 0.21 GHz if they are tuned (the step size is determined by tuning range of the fine etalon and by the number of bits of the employed DAC). The electromechanical actuator of the selective reflector (SR) is fabricated of piezoceramics. Variation of the base of the selective reflector provides a tuning range of 22.5 GHz (three regions of dispersion of the selective reflector). The tuning step of the selective reflector is 0.345 GHz or it can be reduced down to 0.030 GHz if the resonator length is varied simultaneously. The control voltage is applied to SR piezoceramics from a 10-bit digital-to-analog converter through a high-voltage amplifier. The piezoceramic actuator of an end mirror determines the range of continuous linear tuning that expands over 3 GHz. Continuous frequency tuning is provided by an automatic frequency tuning system. When the voltage applied to the piezoceramic actuator of the end mirror of the resonator reaches its maximum, the special device of the automatic frequency tuning system resets the actuator (in this case, the lasing frequency remains unchanged). Then further tuning of the lasing frequency is possible.

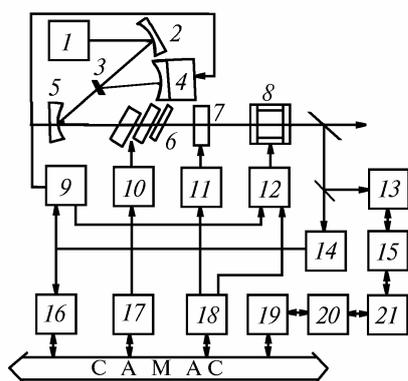


FIG. 1. Single-frequency dye laser with automatic frequency control system: 1) argon pumping laser, 2) pumping mirror, 3) dye jet, 4) end mirror of the resonator, 5) rotating mirror of the laser, 6) Lyot filter, 7) fine Fabry-Perot etalon, 8) selective reflector, 9) automatic frequency tuning system, 10) electromechanical actuator of the Lyot filter, 11) electromechanical actuator of the fine etalon, 12) high-voltage amplifier, 13) wavelength measuring device, 14) photodetector, 15) interface of the wavelength measuring device, 16) analog-to-digital converter, 17) control module of the stepping motor, 18) digital-to-analog converter, 19) CRATE-CAMAC controller, 20) interface of the CRATE-CAMAC controller, 21) computer.

Lasing frequency was measured by the Spektron-IV wavelength measuring device developed at the Institute of Physics of the Belorussian Academy of Sciences. Spectral range of measurements is 440–1060 nm, relative measurement error is 0.0004%, and one measurement cycle lasts 0.25 s.

A CAMAC system is used for shaping of control signals for lasing frequency selectors and for collection of experimental data on the spectra being studied. Standard CAMAC modules are used such as digital-to-analog converters, control module of the stepping motor (CMSM), and analog-to-digital converters.

A computer links all modules of the frequency control system and controls the lasing frequency by a special automated program. Two interfaces serve for information exchange among the wavelength measuring device, CRATE-CAMAC controller, and computer.

The lasing frequency is controlled in two ways:

1. By an algorithm of tuning to a fixed frequency with the help of the Spektron-IV device used for frequency measuring with an error of the order of 500 MHz. Instrumental constants of the electromechanical actuators (minimal tuning step of the selector), Lyot filter, fine Fabry-Perot etalon, selective reflector, regions of free dispersion of the fine

etalon and selective reflector, and initial frequency are used as input data. Next, the current lasing frequency is measured, and the direction and the number of tuning steps for all selectors are calculated. After tuning of the selectors at preset number of steps, lasing frequency is measured again, and tuning is terminated if the difference between the measured frequency and the given frequency falls within the limits of the experimental error, otherwise, it is continued to decrease this difference.

2. By an algorithm of frequency tuning over the range of lasing of dye, which is implemented in the following steps:

a) Step-by-step tuning of lasing frequency. The step size can be changed depending on a specific problem. Minimal step size is determined by the lasing linewidth.

b) Collection of experimental data after every step and their statistical processing. The number of measurements may be changed as dictated by the conditions of the experiment.

The algorithm implements step-by-step tuning of the selective reflector (SR) of the laser, whereas other selectors are tuned to the SR to preserve coincidence of their transmission band centers. It should be noted that the Lyot filter and the fine Fabry-Perot etalon are tuned programmatically, whereas the laser resonator is tuned to the SR by means of a specially designed electronic unit called automatic frequency tuning system. Tuning range of the selective reflector is limited by the potentials of its piezoceramic actuator and is about 22.5 GHz (three regions of free dispersion). After laser has been tuned to 22.5 GHz, the selective reflector resets. In so doing, the lasing frequency remains unchanged, since the mode of the selective reflector spaced from its initial value by three regions of free dispersion, i.e., by 22.5 GHz, determines the lasing frequency.

Analogous technique is applied to the fine etalon too. When the etalon is tuned over one region of dispersion (210 GHz) and the potentialities of the electromechanical actuator have been exhausted, the actuator resets, and the lasing frequency is determined by a neighbouring mode of the fine etalon. The lasing frequency is measured with minimum possible step determined by error of measuring device and is multiple of tuning step size.

In conclusion, we present the specifications of the dye laser.

Lasing linewidth	
during 3 min, no more than, MHz	30
Minimal tuning step, MHz	30
Continuous tuning range, GHz	3
Radiant power (with a pumping power of 3 W), mW	80
Spectral range of operation, nm	580–610

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