Tunable band-stop filter of a laser biharmonic spectrometer and its calibration

G.E. Kulikov

Institute of Atmospheric Optics,
Siberian Branch of the Russian Academy of Sciences, Tomsk

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A tunable band-stop optical filter protecting the linear photodetector array of a laser biharmonic spectrometer against high-power radiation is described. The filter is calibrated by an automatic procedure that hastens the process and permits checking the alignment of the filter interferometer just in the optical system of the spectrometer.

To study the re-emission of molecular media excited by a two-frequency optical field and to check the hypothesis on the generation of a field with high angular momentum,[1,2] a biharmonic laser spectrometer is now under development. The spectrometer includes (a) tunable biharmonic laser emitter consisting of two Nd:YAG laser heads and frequency doublers,[3] (b) optical system and a cell; (c) DFS-452 grating spectrograph and ILX-511 linear CCD array; (d) CAMAC units, control computer, and software. A feature of the optical arrangement under consideration is the need to record re-emitted radiation propagated in the same direction as the pump radiation. A high-power light beam, incident on a linear photodetector array, masks the studied signal and may cause a damage of the photodetector cells. This circumstance forces us to introduce a stop-band filter into the optical system of the spectrometer.

The filter should ensure continuous suppression of the pump biharmonic components at laser tuning in the range $\Delta\lambda_{1,2} \approx (18526 \pm 4)$ cm^{-1}, but transmits the studied re-emitted radiation with the wavelength in the region of half-sum of the pump biharmonic wavelengths.

As a basic element of the optical filter, we took a Fabry–Perot interferometer (FPI) tuned so that the next transmission peak was nearby the frequency of the signal under study. Optical connection of the interferometer with a cell for the studied gas and generation of a parallel optical beam is provided by the optical arrangement shown in Fig. 1 and consisting of the lens *L2* with the focal length F_1 = 150 cm and the telescope T with a micro-objective. A round diaphragm ∅ ~ 0.5 mm and the lens *L3* with the focal length F_2 = 61 mm are mounted behind the interferometer. The interferometer (laboratory version of the interferometer fabricated by the Scientific & Production Association "Angstrem") cavity spacing is tuned by applying the continuous voltage (0 –150 V) to piezoceramic plates.

The voltage level is specified by the computer program and set by the CAMAC unit of the digital-to-analog converter (DAC) supplemented with a high-voltage generator (Fig. 2).

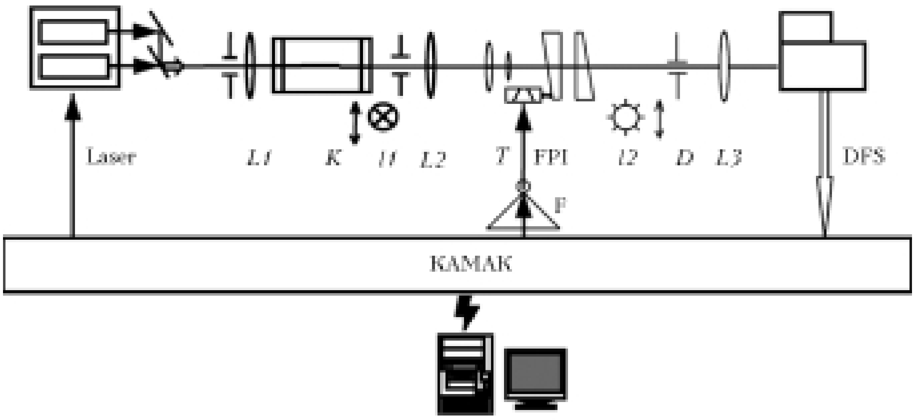

Fig. 1. Layout of the optical system: lenses *L1*, *L2*, *L3*, cell *K*, telescope *T*, retractable KGM12/100 lamp *l1*, retractable TN-0.5 neon lamp *l2*, Fabry–Perot interferometer (FPI), diaphragm *D*, voltage generator and FPI piezodrive F; DFS spectrograph and linear photodetector array.

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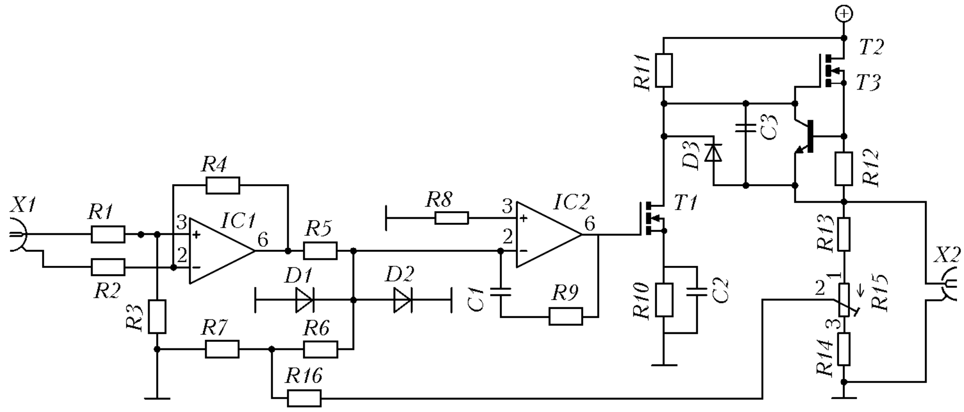

Fig. 2. Electric circuitry of the interferometer piezodrive.

The signal from the DAC comes to the differential amplifier *IC1*, which allows decreasing the in-phase noise. The *IC2* chip plays the role of an error amplifier, whose inverted input receives the input signal along with the feedback voltage from the FPI piezoceramic coming through the divider *R13–R16*. The circuitry *C1–R9* allows eliminating the self-excitation of the amplifier *IC2*. The output cascade of the generator is made using the classical scheme.[4]

The interferometer has no thermo- and barostabilization, and its parameters and settings markedly vary with time. Therefore, the operation with the band-stop filter cannot be reduced to simple setting of a certain level of control voltage, and every time it should begin from checking the alignment and prior determination of the filter amplitude-frequency characteristic (AFC).

To determine the filter AFC and check the interferometer alignment, the following technique and automatic procedure were used.

1. Rough determination of the filter AFC.

(a) A KGM12/100 filament lamp is introduced into the spectrometer, the portions of the lamp spectrum nearby $\lambda \sim 530$ nm are recorded in the absence of the interferometer (reference spectrum) and with the interferometer installed. The reference spectrum is recorded only once and then it is simply read from the computer memory, which permits avoiding interferometer rearrangement. To compensate for the frequency shift arising at such an approach, we use an additional procedure of fitting by the frequency scale, employing, as a reference, the spectral lines of a TN-0.5 neon lamp introduced into the optical system before the beginning of its operation.

(b) The process of recording is repeated at the gradual increase of the control voltage across the interferometer plates. The recorded spectrograms are normalized, subtracted from the reference spectrum, and the search for the wavelengths corresponding to peaks on the spectrogram is carried out. The table "control voltage/wavelength" is compiled.

2. Filter calibration.

(a) the second laser channel is turned on (without the amplification cascade), the laser wavelength is set at the origin of the tuning range, and the spectrogram corresponding to a laser pulse is recorded;

(b) such a level of the control voltage at the interferometer is sought (through stepwise increase of the voltage) that the output signal of the spectrograph is maximum. The output signal is understood as the total level of the signal from the four neighboring photodetector cells corresponding to the peak in the recorded spectrogram;

(c) the spectrum of laser radiation transmitted through the filter is recorded at scanning of the laser wavelength. For each scanning step, the procedure of search for the control voltage is repeated;

(d) the table "control voltage/wavelength" is compiled;

(e) the coefficients of the interpolation polynomial that describe the dependence of the central frequency of filter transmission on the control voltage applied to the filter are determined.

Thus, we obtain two tables describing the wavelength dependence of the positions of the filter transmission peaks. The first table is compiled quickly (for 2 min), but it is useless for filter tuning. The second table accurately describes the filter AFC, but to obtain it takes about 40 min. Nevertheless, the first table correlates with the accurate one and is used to refine the control voltage levels without repeating the calibration procedure. In this case, we can judge on the quality of the alignment of the interferometer just in the optical arrangement of the spectrometer – the failure of constructing the coefficients of the interpolation polynomial or significant deviation of the coefficients from the reference values are indicative of the need in a more accurate alignment of the interferometer. This allows the long accurate calibration procedure to be carried out only once (when setting the interferometer).

The described process of interferometer calibration is carried out automatically, by the *scenario* of the automated data acquisition and processing system.[5] The coefficients of the interpolation polynomial obtained during the calibration are transmitted to the laser and interferometer tuning procedures.

Figure 3 depicts the spectrograms of laser radiation (without the amplification cascade) at the band-stop filter on and off.

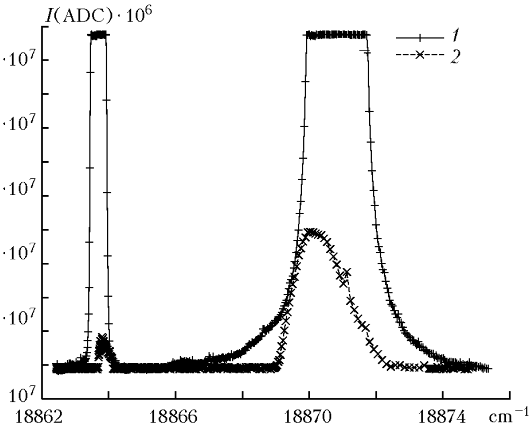

Fig. 3. Laser radiation intensity (in relative units – ADC readouts) at the filter on (*2*) and off (*1*). The spectrograph slit is fully open.

The use of a tunable interferometer in the laser spectrometer allowed us to decrease the pump radiation incident on the linear photodetector array by almost 30 times and, thus, to protect the photodetector array against damage.

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