Measuring gas temperature in Ar-He plasma using diode laser absorption spectroscopy

Ruslan Kuramshin[1,2], Aleksei Torbin[1,2], Alexander Chernyshov[1,2]

[1] Lebedev Physical Institute, Samara Branch, 221 Novo-Sadovaya str., Samara, Russia, 443011
[2] Samara National Research University, 34, Moskovskoye shosse, Samara, Russia, 443086
kuramshinr2001@gmail.com

An optically pumped rare gas laser (OPRGL) is a new laser system that converts the radiation from laser diodes into high-power radiation with a quality close to the diffraction limit. In order to determine the limiting characteristics and optimal operating modes of the OPRGL, it is necessary to create a mathematical model of the active medium. The construction of such a model is complicated by the lack of data on the rate constants of processes involving metastable atoms of heavy rare gases. The operating pressure of the OPRGL is of the order of atmosphere, leading to elevated gas temperatures in the plasma. In view of this, it is necessary to know the temperature dependence of these constants in order to construct an OPRGL model. Therefore, the measurement of the rate constants must be accompanied by the measurement of the gas temperature in the plasma, which is the goal of our work.

In the experiment, the production of metastable argon atoms $1s_5$ was carried out in a pulse-periodic discharge ignited between a pair of titanium electrodes located inside the discharge chamber. Radiation from a tunable diode laser with a wavelength of about 912.3 nm was introduced into the interelectrode space. In front of the camera, the beam was split and entered the reference channel and the Fabry-Perot interferometer. In the signal channel, the power of the laser beam passing through the plasma was measured as a function of time. The time scale was converted to a frequency scale using a Fabry-Perot interferometer.

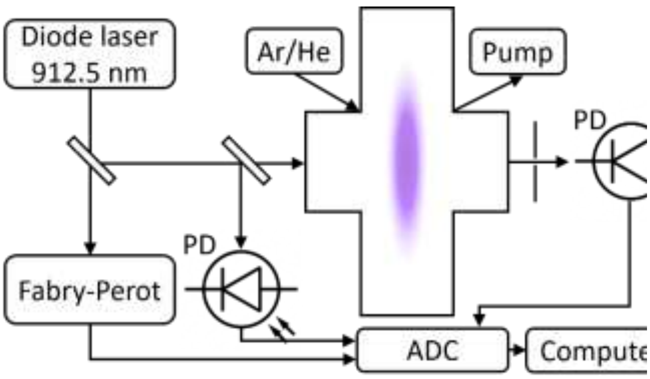

Figure 1 – Experiment scheme

Approximation of the experimental absorption line by the Voigt profile using the Levenberg-Marquardt algorithm allowed the determination of the full width at half maximum (FWHM). The Voigt contour is a convolution of the Gaussian and Lorentz functions, and the dependence of the FWHM of the Voigt profile on temperature and pressure is determined by the expressions:

$$\mathrm{FWHM} = 0.5346 * \mathrm{WL} + \sqrt{0.2166 * \mathrm{WL}^2 + \mathrm{WG}^2}\,,$$

$$\mathrm{WL} = 2 * 3.22 * p * \xi * (T/300)^{-0.7} * 0.001 + \mathrm{WL}_{\mathrm{las}},$$

$$\mathrm{WG} = \mathrm{WG}_{300}\sqrt{T/300}\,,$$

where p is the pressure in Torr, ξ is the collisional broadening coefficient, $\mathrm{WL}_{\mathrm{las}}$ is the laser spectral linewidth, WG_{300} is the Gaussian broadening at 300 K. A comparison of the experimental FWHM and that calculated using the formula made it possible to determine the gas temperature in the plasma.

The report will present the results of temperature measurements at various experimental parameters.