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STABILIZATION OF SPECTRAL PARAMETERS IN A STRONTIUM VAPOR LASER

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The article provides a review on the laser on strontium vapor and its stabilization, considers the Lamb method and describes laser devices .Authors also consider the characteristics of a strontium vapor laser.

Keywords: Laser, Stabilization, Frequency, Power Meter, Radiation.

A laser is a quantum generator, a source of coherent monochromatic electromagnetic radiation of the optical range. It usually consists of three main elements:

- Source of energy (the mechanism of "pumping" the laser).
– The active zone of the laser.
– Mirror system ("optical resonator»)

The strontium vapor laser is classified as a gas laser on metal vapor. From the multitude of currently existing coherent radiation sources, lasers at self-limiting transitions in metal vapor occupy a special place due to the unique combination of output parameters: high repetition rate, high peak and average power.

A strontium laser contains:

- A gas discharge tube with a hinged strontium inside it and with electrodes at its ends;
- A passing flat mirror and a return flat mirror, wherein mirrors are arranged on opposite sides of gas-discharge tube in such a way that they create a laser resonator;
- Radiation power meter, for example IMO-2H;
-A high-voltage pulsed electric power unit;
-Computing unit.

In a laser at a self-limiting transition of an atom and a strontium ion, the generation is obtained at eight wavelengths: 6.45 μm, 3.06 μm, 3.01 μm, 2.60 μm, 2.69 μm, 2.92 μm, 1.09 μm and 1.03 μm [7].

Let us consider the results of systematic laser studies on strontium vapor. The strontium vapor laser is characterized by the presence of simultaneously «self-limited» generation on atoms Sr1 and ions Sr2. The most powerful line of generation on strontium atoms λ = 6.456 μm lies in the middle infrared region of the spectrum. Generation was observed on three strontium lines with λ =

6.456; 3.0665; 3.0111 μm; and two strontium ion lines with λ = 1.0917 μm and 1.0330 μm.

Experiments using a set of light filters have shown that the first burst of generating power observed 5-8 minutes after activation of the pulse discharge is due to a significant contribution to the total power generation of ion lines. As the temperature rises to optimum, the total power of all Sr2 lines decreases. About 15% of the generating power was concentrated in the line with λ = 6.456 μm Sr1, 20% in the lines with λ = 3 μm Sri, and 5% in the lines with λ = 1 μm Sr2 15–20 minutes after the activation of the discharge. A strontium vapor laser is characterized by a relatively narrow temperature range, thatis why it is even insignificant [6].

Overheating of the working medium causes the generation to disappear by λ= 1.0330 and 1.0917 λ = 6.456 μ m. At the pressure of the buffer gas (helium) ~ 10 Torr, the generation was observed on the lines λ= 6.456;1.033; 1.0917 μm, and on λ= 3 μm was not present. It has been established that the highest average generating power is observed at a helium pressure of ~ 80 Torr [5,7].

Now let us look at the kinds of stabilization of the laser parameters. There are two types of stabilization of the laser radiation parameters: passive and active. Passive stabilizing techniques, i.e. without external feedback, are application of rigid resonators from materials with a low thermal expansion coefficient and a high Jung module value. It is quartz. The inventive method consists in using thermostats, heat screens and in placing a laser inside a vacuum chamber, in sealing an optical path in a resonator, including vacuum, in using stabilized power sources. Passive stabilizing techniques can provide a frequency instability of $\sim 10^{-8}$.

Active stabilization is carried out by means of feedback with the aid of electronic devices producing an error signal by comparing output and support signals. In the construction of systems for stabilizing radiation power, it is necessary to know the amplitude and spectral composition of fluctuations, temperature conditions. The radiation power is stabilized either outside the laser or by stabilizing the laser parameters. In the first case, the radiation power is controlled by elements with controllable transparency. They are different modulators: mechanical, interference, electro-optical, magneto-optical, acoustic-optical, electrochromic and others. Crystal-based electro-optical modulators (KN2RO4), (NH4H2PO4), (KD2PO4), lithium niobic [1]. A light beam passing through such a crystal acquires a phase shift corresponding to the phase modulation of light. The transparency of these crystals does not depend on the radiation power in the range of 1-15 W, but is characterized by low inertia (~ 10^{-12} c). Disadvantages include hygroscope properties of crystals, large losses of intensity up to 30%. Acoustic-optical modulators have small losses (~ 1%), low power for control (units W), allow for modulation of power up to 15 W. In order to obtain maximum power, the radiation usually operates in multi-mode . If the laser is necessary for measurement, it works in single-mode or single-frequency modes. Transverse modes are more easily selected in a confocal resonator. One way to select the transverse types of oscillations is to select the diameter of the active element in such a way that it plays the role of a peculiar diaphragm that passes through the radiation of zero-fashion but does not pass through the higher-order modes.

Stabilization of the frequency of laser radiation by the Lamb dip. The Lamb dip occurs in any gas lasers operating on the same mode with Doppler broadening of the transition line. The laser output power curve has a dip at the center transition frequency (Figure 1).

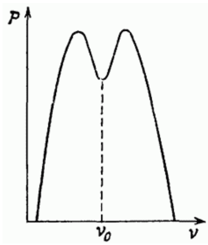

Figure 1. Lamb Pass [1].

A curve of this shape can be produced experimentally when the resonator length is changed in a smooth manner and is related to the dependence of the frequency of radiation generation with the rate of motion of atoms and the presence of an optical resonator. Since its width is much less than the width of the laser transition line, the position of the bottom of the Lamb gap is fixed with a high degree of precision [1].

The Lamb reversible failure method provides better stabilization (see fig. 2). A ditch with a gas that is not excitable is placed inside the resonator. At the same time, the Lamb failure is formed when the absorption line of this gas is exactly the same frequency as the center of the laser amplification line. During laser generation, absorption in the absorber gas must have a minimum at ν =ν 0. This results in a maximum output at ν =ν0.

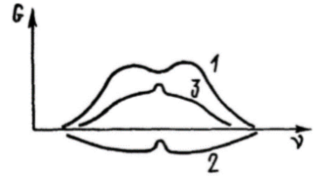

Figure 2. To Lamb absorption cell failure method: 1 – active medium amplification; 2 – gas absorption; 3 – total amplification [1]

The position of the center frequency of the absorption curve of the absorber gas is much more stable than the position of the center frequency of the active media amplification line (no current flows through the absorber gas and it is at a lower pressure than the active medium). The requirements for a absorbent in a laser include a large population of the lower state; a long life of the excited state; a large relative molecular mass [1].

The laser radiation frequency is modulated on the first harmonic of the reference generator of the automated frequency adjustment system, and the support signal of the synchronous detector is in the form of a third harmonic. Under these conditions, the output of the synchronous detector corresponds to the third derived circuit of the laser radiation power. Therefore, the method of laser frequency stabilization according to the third derivative is also called the method of stabilization according to the third harmonic. In the signal of the third harmonic, the laser radiation power does not depend on the frequency change. Modulation of the laser radiation frequency leads to modulation of the radiation intensity. With a small change in frequency, the displacement of the working point along the radiant line of radiation power results in harmonic changes in the intensity of the laser radiation. The presence of non-linearity on the contour (peak due to saturated absorption) gives a non-linear change of intensity, i.e. harmonics appear. If, after the photodetector, the signal arrives at the input of an amplifier tuned to one of the harmonics, the automated frequency adjustment system will only respond when set to peak. The higher the harmonic, the more sensitive the system is. But the amplitude of the harmonic drops with the increase in frequency, so you have to limit it to low harmonics. The instability of the radiation frequency is 10^{-10}-10^{-12} [4].

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