PACS numbers: 42.55.Lt; 42.68.Wt
DOI: 10.1070/QE2000v030n12ABEH001877

NH_3 laser as a radiation source for a two-frequency lidar

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Abstract. An NH_3 laser pumped by a CO_2 laser with spatial matching of output beams is investigated. Such a laser can be used as a radiation source for a two-frequency lidar operating in the range from 11 to 13.5 μm.

Much recent attention is being given to devices for remote environment monitoring. Lidar is a laser device of this kind capable of detecting the concentration and composition of contaminating gases in atmosphere [1]. Lidars may be either multifrequency for measuring the absorption and scattering spectra in a single laser pulse or two-frequency. The specific feature of the two-frequency lidars is the use of the reference radiation at a fixed frequency and the detection of absorption and scattering spectra in a series of pulses by varying the frequency of probe radiation.

The most popular are CO_2 lidars operating in the spectral range between 9 and 11 μm [2]. The studies of ammonia laser pumped by a CO_2-laser make it possible to build a lidar operating at longer wavelengths between 11 and 13.5 μm [3 – 5], where the absorption spectra of many hazardous molecules (freons, dioxines, etc.) are located. It is most appropriate to use an NH_3 laser for building a two-frequency lidar with the reference signal formed by a part of the pump radiation [3, 5].

One important problem that arises in designing two-frequency lidars is spatial matching of laser beams of two different frequencies. Note that in studying laser-pumped NH_3 lasers, optical schemes were specially developed for a spatial separation of the pump and output beams propagating at an angle to each other. The use of such schemes in two-frequency lidars [3] considerably complicates the device as a whole because an optical system should be designed for spatial matching of the pump and NH_3 laser beams within the entire spectral range of lasing. In paper [5], an optical scheme of a two-frequency lidar radiator is described in which the matching of beams was performed using highly reflecting mirror. However, in this case the requirements to the quality of optical elements and their alignment are rather high, which is especially undesirable in mobile devices.

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Received 15 August 2000
Kvantovaya Elektronika **30** (12) 1105 – 1106 (2000)
Translated by N A Raspopov

In this paper, we study the optical scheme of a tunable NH_3 laser with the automatic matching of the pump and output beams for all emission wavelengths of the NH_3 laser.

The optical scheme of the laser is shown in Fig. 1. Radiation of a CO_2 laser with a pulse energy of 2.5 J and the beam cross section 3×2 cm was tuned to the $9R(30)$ line with the help of a 100 lines/mm diffraction grating *7* and directed approximately perpendicular to the 75 lines/mm grating *8*. The pump radiation reflected in the first order of the grating was incident on a cell with an active medium length of 1.8 m that was filled with the $NH_3 : N_2 = 1 : 20$ mixture at a total pressure of 10 Torr. The cavity of the NH_3 laser was formed by a semitransparent mirror *1* (a germanium plate) and the highly reflecting mirror *2* that were coupled via the zero order of grating *8*. The highly reflecting mirror *3* was placed perpendicular to the radiation of a certain wavelength reflected in the first order of grating *8*. The output frequency of an NH_3 laser was tuned by rotating mirror *3*.

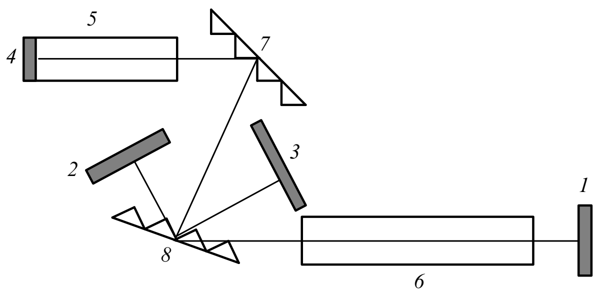

Figure 1. Optical scheme of a tunable NH_3 laser for a two-frequency lidar: (*1*) output mirror; (*2 – 4*) highly reflecting mirrors; (*5*) active element of a CO_2 laser; (*6*) active element of an NH3 laser; (*7*) 100 lines/mm diffraction grating; (*8*) 75 lines/mm diffraction grating.

In this geometry, lasing was obtained at five frequencies 858.6 cm^{-1} (the $aP(4,0)$ transition), 847.4 cm^{-1} (the $sP(6,k)$ transition), 832.0 cm^{-1} (the $aP(5,3)$ transition), 828.0 cm^{-1} (the $sP(7,k)$ transition), and 816.8 cm^{-1} (the $aP(6,0)$ transition) with pulse energies of 80, 60, 50, 100, and 30 mJ, respectively. The background radiation energy at the frequency 1084 cm^{-1} was 350 mJ. During the measurements, the pump radiation was suppressed with a narrow-band filter. The low efficiency of an NH_3 laser is caused by a low Q factor of the cavity. Further optimisation of the reflection coefficient of mirror *1*, the pressure and composition of the laser medium, and, mainly, an increase in the pumping energy will provide a broader spectral range of lasing and considerably increase the efficiency of an NH_3 laser in the range between 11 and 13.5 μm.

Thus, the NH_3 laser emitting two spatially matched beams (the 1084 cm^{-1} beam from a CO_2-laser and a tunable beam from an NH_3 laser} can be used as a laser source in a two-frequency lidar operating in the spectral region from 11 to 13.5 μm.

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