indicates that by influencing the spectral characteristics of the POPOP molecules, ether increases the amplification cross section, which increases the lasing efficiency both in vapors and in solutions. It would be interesting to determine the dependence of the lasing efficiency on the ether pressure for POPOP vapor lasers.

Our results show that the lasing characteristics of POPOP in vapors and solutions are similar, indicating that POPOP molecules retain their good lasing properties at elevated temperatures and that gaseous media can be used in practice in dye lasers. The thermal stability of the lasing characteristics of POPOP molecules also makes these potentially useful for lasers utilizing solid optically homogeneous porous matrices[19] and as the initial medium for aerosol lasers.[20]

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Translated by R. M. Durham

BRIEF COMMUNICATIONS

Efficient generator of a two-photon field of visible radiation

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(Submitted January 20, 1981)
Kvantovaya Elektron. (Moscow) 8, 1563–1565 (July 1981)

A description is given of an optimal system for parametric conversion of one-photon light into a two-photon field. This system is suitable for absolute calibration of photodetectors throughout the visible range without the use of a standard source for comparison. Tuning curves of such a parametric converter are calculated and verified experimentally. The efficiency achieved in this method of generation of a two-photon field (10^6 of two-photon pairs per second in a spectral band $\Delta\nu = 10$ cm^{-1} wide) makes it possible to calibrate photodetectors to within at least 3–4% after accumulation of a signal for a time of the order of 100 sec.

PACS numbers: 42.65.Cq

The method of absolute calibration of photodetectors based on the statistical properties of a two-photon field[1] depends on the existence of an efficient generator of a two-photon field which must have the following properties: a high density of the two-photon flux; a high precision in the determination of the values of the frequencies of the two photons forming a pair, directions of their propagation, and polarizations; a small time indeterminacy of the moments of transit through given points in space.

A shortcoming of a two-photon field generated as a result of two-photon luminescence is the absence of a unique relationship between the directions of emergence of photons in a pair and the practically spherical angular distribution of the radiation. This makes it difficult to identify photons as belonging to a given pair, reduces the number of photons in a single mode, and—consequently—makes it practically impossible to use two-photon pairs in absolute calibration.[2] A two-photon field generated as a result of hyperparametric scattering of light is characterized by a unique relationship between the directions of emergence and frequencies in a two-photon pair, but the number of such pairs is very small. For example, when the pump density is ~ 100 W/cm^2, the average flux of two-photon pairs does not exceed 10^{-2} sec^{-1} in a $\Delta\nu = 50$ cm^{-1} band in the visible part of the spectrum.[3]

A two-photon field generated by the three-wave parametric scattering of light in noncentrosymmetric media is largely free of these shortcomings. In a medium with a susceptibility which is a quadratic function of the field an elementary parametric scattering event results in a spontaneous decay of a pump photon of frequency ν_3 with a wave vector $\mathbf{k}_3$ into a pair of photons of frequencies ν_1 and ν_2 with wave vectors $\mathbf{k}_1$ and $\mathbf{k}_2$, which satisfy the relationships

$$\nu_3=\nu_1+\nu_2,\quad \mathbf{k}_3=\mathbf{k}_1+\mathbf{k}_2. \tag{1}$$

The conditions in Eq. (1) together with the dispersion characteristics of a medium determine uniquely the frequency and angular spectra of the scattered radiation emerging from a noncentrosymmetric medium and give a unique relationship between the frequencies and wave vectors of photons in a two-photon pair.

The number of substances suitable for such conversion of one-photon pump radiation into a two-photon field by parametric scattering is smaller than the number of materials in which hyperparametric scattering can take place but this is compensated by a much higher intensity of the two-photon flux, which is 7–8 orders of magnitude greater than the flux in the hyperparametric case. When the pump power density is 1 W/cm^2 in a lithium niobate crystal, the brightness temperature of the radiation at frequencies ν_1 and ν_2 can reach several degrees Kelvin. The difference between the times of emergence of photons belonging to the same two-photon pair does not exceed 10^{-11}–10^{-12} sec and is governed mainly by the different optical paths of phonons due to the dispersion of the medium. The interdeterminacy of the directions of emergence of photons can be characterized by the angular width of the frequency-angular spectrum,[4] which does not exceed 30′ if there is no absorption at frequencies ν_{1-3} when the pump wave is plane. The density of a two-photon flux in the case of such three-photon parametric scattering depends linearly on the pump power, which is limited by the parameters of the currently available lasers and by the optical strength of the crystals employed for this purpose. The pump wavelength selection is determined by the spectral range in which two-photon pairs are needed. The most convenient conversion conditions are obtained for near-degenerate scattering, i.e., when $\nu_3 \approx 2\nu_1 \approx 2\nu_2$.

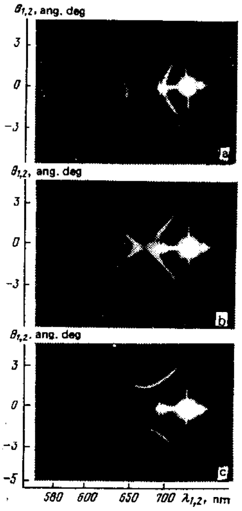

FIG. 1. Calculated tuning curves of a two-photon field in a lithium iodate crystal plotted for the pump wavelength λ_3 = 325 nm and three values of the angle θ_0: 1) 56°; 2) 58°; 3) 60°. Interaction of the oo–e type; λ_1 and λ_2 are the scattered-light wavelengths; $\theta_{1,2}$ are the angles of emergence of photons outside the crystal; the open circles and the black dots on curves labeled by the same number correspond to parametrically coupled photons.

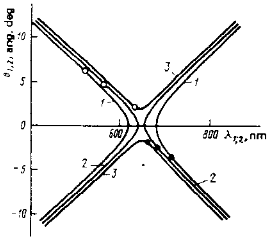

FIG. 2. Scattering spectra of a two-photon field in a lithium iodate crystal obtained for the following angles θ_0: a) 56°; b) 58°; c) 60°.

At present the most suitable crystal for the conversion process described above is lithium iodate (LiIO$_3$).[5] This material is transparent in a wide spectral range (0.3–5.5 μ). Practically throughout this range the scattering conditions are degenerate and the wave vectors are nearly collinear. Lithium iodate is characterized by a quadratic susceptibility. The real component of the quadratic susceptibility tensor reaches 10^{-8} cm/dyn$^{-1/2}$ (Ref. 6). Figure 1 shows the calculated dependences of the angles of emergence of photons in parametrically coupled modes on the photon wavelengths for three different angles θ_0 between the vector $\mathbf{k}_3$ and the optic axis Z when the pump wavelength is λ_3 = 325 nm. In this case the most efficient generation of a two-photon field is observed in the frequency range 15 000–19 000 cm^{-1} (550–750 nm). Figure 2 shows the experimentally determined dispersion dependences. A cadmium vapor laser provided a power of 5 mW at the wavelength of 325 nm. When the lithium iodate crystal was 2 cm long, this made it possible to generate a two-photon flux of 10^6 sec^{-1} in a spectral interval $\Delta\nu$ = 10 cm^{-1}.

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Translated by A. Tybulewicz

Radiative characteristics of an injection laser with a zigzag mesastripe AlGaAs–GaAs heterostructure

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(Submitted January 23, 1981)
Kvantovaya Elektron. (Moscow) 8, 1565–1567 (July 1981)

A description is given of an injection laser with a zigzag mesastripe structure. Spike-free stimulated emission was observed until the threshold was exceeded by a factor of 2.5. In the cw regime the maximum single-frequency power exceeded 10 mW. When the cw power was 4–5 mW, the laser operated for 10^3 h at 300 °K without significant degradation.

PACS numbers: 42.55.Px

One of the low-threshold heterojunction lasers has an "elevated" mesastripe heterostructure[1-3] ensuring strong lateral confinement of the electric and optical radiation in channels etched on both sides of the active region. However, even a narrow (for example, about 4–6 μ wide) mesastripe represents a multi-mode dielectric waveguide because of a large change in the refractive index ($\Delta n \approx 2.6$) at the lateral surfaces. Multimode excitation can be prevented by employing a zigzag-shaped mesastripe heterostructure (Fig. 1). In our case the active region was in the form of a rectilinear stripe under a contact of the same shape, whereas the mesastripe structure was wide and its zigzag lateral walls approached and moved away from the active stripe with a period of 50 μ. The shape of the lateral walls quenched higher-order transverse modes.

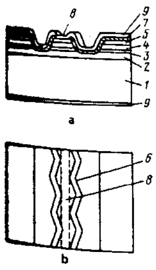

FIG. 1. Schematic representation of a laser diode with a zigzag mesastripe heterostructure viewed from the end (a) and from above (b): 1) n-type GaAs substrate; 2) wide-gap n-type AlGaAs emitter; 3) undoped active n-type AlGaAs layer; 4) wide-gap p-type AlGaAs emitter; 5) contact p^+-type GaAs layer; 6) mesastripe structure; 7) insulating SiO_2 film; 8) stripe contact with the p-type side; 9) metal-film contacts with p- and n-type sides of the diode.

A planar two-sided heterostructure of the usual type was prepared by liquid epitaxy on a GaAs substrate oriented along the (100) plane. The structure consisted of a sequence of layers shown in Fig. 1a. The thickness of the active layer was 0.2–0.3 μ. Contact photolithography was used to form a zigzag mesastripe by etching to a depth greater than or equal to the depth of the active region. The resultant relief surface was coated by a film of silicon dioxide in which a stripe window was etched away to form a contact with the p-type side of the structure. Two variants were investigated: in one the width of the mesastructure was 35 μ and the stripe contact was 15 μ wide; in the other, the same dimensions were 15 and 6–8 μ, respectively. The method employed made it possible to control the width of the laser channel during etching to within a few microns.

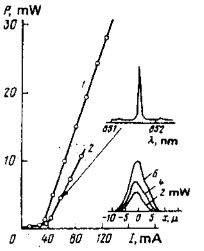

FIG. 2. Watt-ampere characteristics in the pulsed (1) and cw (2) regimes; the insets show the emission spectrum for 4 mW power (at the top) and intensity distributions in the near-field zone obtained for output powers of 2, 4, and 6 mW (lower part). Mesastripe width 15 μ, contact width 6–8 μ, resonator length 250 μ, temperature 300°K.