SO_2 SUBMILLIMETER LASER GENERATING AT WAVELENGTHS 0.141 AND 0.193 mm

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Submitted 26 March 1968
ZhETF Pis'ma 7, No. 11, 408 (5 June 1968)

We observed relatively strong laser emission at wavelengths 0.141 and 0.193 mm by discharge in a gas medium containing SO_2 and He. The laser operated continuously with a discharge current 0.15 A.

The laser glass tube, 2.5 m long and with inside diameter 56 cm, was cooled with running water to 14°C. The annular anode was made of molybdenum, and the hollow water-cooled cathode was made of aluminum. The resonator was made up of two mirrors of diameter 60 cm and radius of curvature 5 m. The radiation output aperture in one of the mirrors had an 8 mm diameter. The mirrors were made of glass sputtered with gold in vacuum. The seal window was made of saphhire 0.3 mm thick.

The laser operated with continuous gas-mixture supply. Using pure SO_2, the optimum power is reached at a pressure 2.1 mm Hg. Addition of helium (total pressure 3.6 mm Hg) stabilizes the discharge and increases the radiation power by one order of magnitude.

The discharge in the described gas mixture has a characteristic blue color. After prolonged operation, a deposit of sulfur is produced in some sections of the tube; it can be readily cleaned by discharge in air.

The wavelength was measured with a Fabry-Perot interferometer with reflectors made of wire grids, and the power was measured with a calorimeter. The radiation was determined with a pyroelectric receiver using a triglycine sulfate crystal. It is interesting to note that both waves were also registered with a crystal detector mounted in a waveguide of 0.5 x 0.2 mm cross section, with a silicon-tungsten thermocouple detector. The latter circumstance makes it possible to measure exactly the frequency by radiotechnical methods. The power was 1.5 and 0.3 mW at wavelengths 0.141 and 0.193 mm respectively.

The presently known strong lines in the submillimeter band are those of HCN molecules (λ = 0.336 mm and λ = 0.311 mm) and H_2O molecules (λ = 0.118 mm and λ = 0.079 mm).

The discovered SO_2 emission lines (λ = 0.141 mm and λ = 0.193 mm) can also be classified as strong, with a very favorable location in the band relative to the HCN and H_2O lines.

ENERGY SPECTRUM AND ANGULAR DISTRIBUTION OF THE PENETRATING COSMIC-RAY COMPONENT AT MOUNTAIN ALTITUDES

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Submitted 1 April 1968
ZhETF Pis'ma 7, No. 11, 409-412 (5 June 1968)

The characteristics of the penetrating component at the 20 m w.e. depth were investigated with the aid of a setup consisting of an ionization calorimeter and a hodoscope of gas-discharge counters. The array was located at an altitude of 3340 m above sea level at the Tyanshan' High-mountain Scientific Station of the Physics Institute of the USSR Academy of

Sciences.

The ionization calorimeter consists of four rows of ionization chambers separated by a lead absorber. The thickness above the top seven rows is 2.5 cm and above the others 5 cm. The chambers in neighboring rows are located in mutually perpendicular directions, forming a sensitive area of $\sim 9\ m^2$. The number of chambers in each row is 24. Each chamber is connected to its own registration channel, making it possible to measure pulse amplitudes in the range 50 000 - 500 000 relativistic particles. The calorimeter is covered on the top with a "carpet" of 288 counters each of 330 cm^2 area. Two neighboring counters are connected to a hodoscope cell. Information on the pulse amplitudes in the chambers and on the operation of the gas discharge counters was obtained by photographing the recording unit, and also was recorded on magnetic tape and subsequently processed with an M20 electronic computer.

The array operated whenever ionization corresponding to the passage of 600 - 700 or more relativistic particles appeared in the chambers of the calorimeter. In 602 hours of operation of the array we registered approximately 6000 events in which the cascade in the calorimeter produced an ionization larger than threshold. For each cascade we determined its energy and zenith angle [1]. All the properties of the registered cascades can be explained under the assumption that they are produced by the interaction between the muons and the atoms of the absorber [1]. Further analysis of the events was based on the conclusion that at small underground depths the penetrating high-energy component consists of muons.

We analyzed the angular distribution of the cascades with $E \geq 10^{11}$, $\geq 3 \times 10^{11}$, and $\geq 10^{12}$ eV, produced in the seven upper rows of the calorimeter. The accuracy with which the zenith angle θ was determined for these cascades was 6 - 8° in the interval $\theta = 30 - 75°$. Owing to the rapidly drooping energy spectrum of the cascades, the number of events used to plot the angular distribution of the cascades with the next higher energy threshold was always a small fraction of the preceding one, and therefore the constructed distributions are practically independent of one another.

Comparison of each of the three obtained distributions with the distribution expected in accordance with the calculations [2] made under the assumption of a pure "pion" or "kaon" origin of the muons of different energies leads to the same conclusion, namely, the angular distribution of the muons is more isotropic than that calculated for a pure pion source. Figure 1 shows by way of an example the angular distribution of the cascades with $E \geq 3 \times 10^{11}$ eV, compared with the theoretically expected one for muons of different energies produced in π-μ decay. The conclusion of larger isotropy is natural if one takes into account the fact that the cascades with $E \geq 3 \times 10^{11}$, which have a power-law energy spectrum with exponent $\gamma \approx 2.1$, should be produced in accordance with our estimates by muons of average energy $\bar{E}_\mu = (1.2 - 1.5) \times 10^{12}$ eV. Comparison of the angular distributions of the cascades with $E \geq 3 \times 10^{11}$ and $\geq 10^{12}$ eV shows that the angular distributions of the muons with $E_\mu \gtrsim 10^{12}$ eV become practically independent of the energy.

We can attempt to attribute the large isotropy of these distributions to the consider-

able contribution of the K-μ decay to muon generation, which gives an angular distribution that is in much better agreement with experiment. However, an analysis of the energy spectra of all the registered cascades and of the cascades with $\theta \leq 50°$ shows that the obtained spectra contradict, with respect to absolute intensity, the assumption that the K-μ decay plays a noticeable role in the muon production. In the interval $E = 10^{11} - 6 \times 10^{11}$ eV, these spectra agree with the differential spectrum of the muons of the vertical flux

$$\frac{\partial F}{\partial E_\mu} = A \frac{(E_\mu/10^{11})^{-\gamma_\mu}}{E_\mu + E_{cr}}, \tag{1}$$

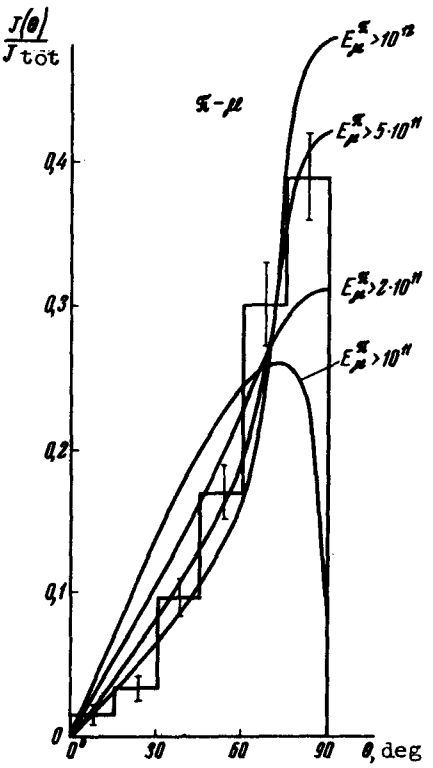

Fig. 1. Angular distribution of cascades with $E \geq 10^{11}$ eV compared with the calculations of [2] for muons produced in π-μ decay.

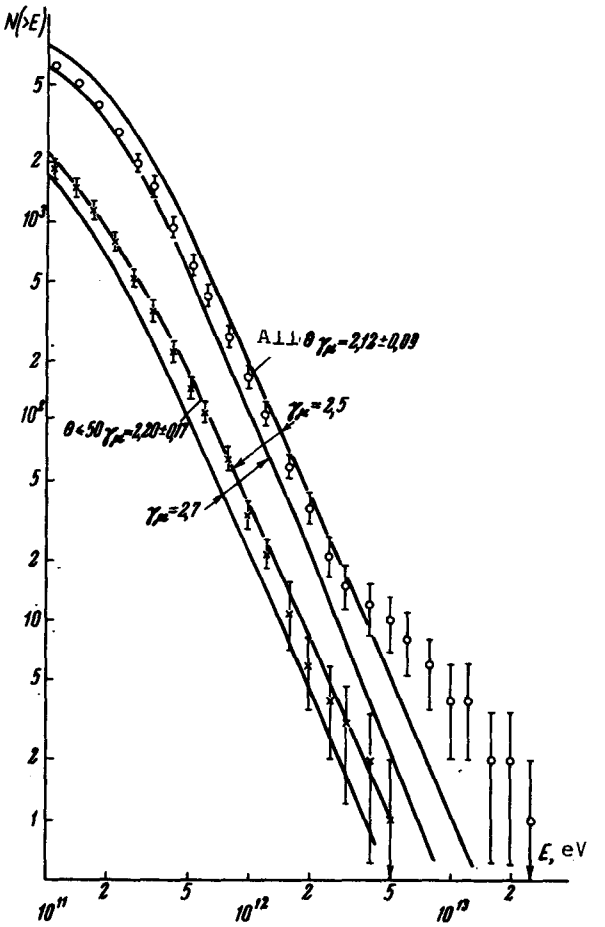

Fig. 2. Energy spectra of all the registered cascades and of the cascades with $\theta \leq 50°$. Solid lines - calculation with muon spectrum of type (1) with $\gamma_\mu = 2.5$ and 2.7 and with constants A and E_{cr} characteristic of the pion generation mechanism. The employed angular distribution was the one obtained experimentally in the present investigation.

where $A = 5.4 \times 10^{-5}$ $cm^{-2}sec^{-1}sr^{-1}$, $E_{cr} = 116$ GeV, and $\gamma_\mu = 2.6 \pm 0.1$, a spectrum characteristic of the pion mechanism of muon production (Fig. 2). Comparison of the energy spectra of all the registered cascades and of the cascades with $\theta \leq 50°$ confirms the conclusion that the angular distributions of the muons with $E_\mu \gtrsim 10^{12}$ eV are practically independent of their energy. The larger isotropy of all the angular distributions can be reconciled with the assumed pion origin of the muons, provided the theoretical calculations are made with a steeper generation spectrum and with a larger muon energy loss than those used in [2]. These refinements are fully justified in light of the results obtained in recent years [3,4].

At energies $E \gtrsim 6 \times 10^{12}$ eV an excess of cascades is observed in comparison with that expected from the spectrum (1) and the usual cross sections for their interaction with matter. This excess can be related to the change in the energy spectrum of the muons or to an increase in the effective cross section for the transfer to the muon of a larger fraction of the energy in the electron-photon component at muon energies $E_\mu \gtrsim 2 \times 10^{13}$ eV.

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SUPERCONDUCTIVITY OF PHOSPHORUS AT HIGH PRESSURES

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Submitted 2 April 1968
ZhETF Pis'ma 7, No. 11, 412-416 (5 June 1968)

Following the recent discovery of the superconducting modifications of Ge, Si [1], Sb [2], Te [3], and Se [4], which arise at high pressures in the fifth group of the periodic system, we are left with two elements, P and As, which can also be expected to exhibit superconductivity upon compression. We report here observation of superconductivity of P in the pressure region 170 - 260 kbar.

The procedure used to obtain the pressures was similar to that used in [5]. The pressure was produced between the planes of Bridgman anvils (Fig. 1, 1) made of VK-3 alloy and placed in a booster. The high-pressure chamber was made up of two discs, 2, approximately 10 - 15 μ thick, and pressed from finely dispersed powder of iron oxide Fe_2O_3, two blocking rings, 3, ~20 μ thick, with inside diameter ~0.5 mm and outside diameter ~1.5 mm, pressed in a special device from a mixture of Fe_2O_3 powder and powdered steatite, and two steatite

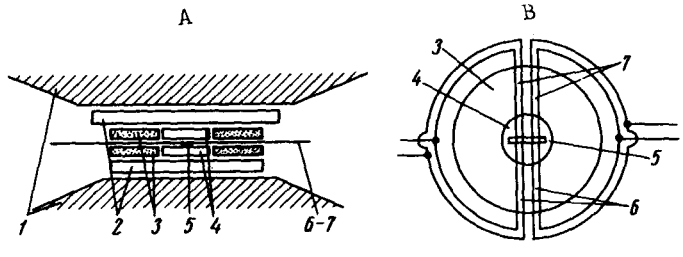

Fig. 1. A. Construction of high-pressure chamber. B. Arrangement of the sample and of the current and potential electrodes.