372-mJ long pulse pyrotechnically pumped laser

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A pyrotechnically pumped Nd glass laser is demonstrated by the use of pyrotechnic flashlamps composed of several chemical materials arranged in a stable plane concave resonator cavity. The flashlamp was made of chemical mixture with oxidant, fuel, and binder. The emission spectrum of pyrotechnic flame covered most of the absorption bands of Nd^{3+} in phosphate glass. Under 4.56-g chemical mixture pumping, long pulse output power of about 5.5 W was achieved.

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There are many applications requiring low-cost, compact, and expendable solid state lasers. One of the biggest problems is the source for pumping the laser rod. Most lasers are pumped by flashlamps or laser diodes which require large batteries and capacitors for energy storage. This makes the size and cost of such lasers be great.

Chemical explosion and pyrotechnical light pumping sources were developed by Kaminskii *et al.* in the end of 1960s[1] and used for the miniature laser radar by Acharekar *et al.* in 1992[2]. In China, Zhu and Xiang have paid attention to this pumping source in recent years[3,4].

In the present work, we prepared a new chemical pumping source and applied it to obtain a long pulse generation in the phosphate Nd glass laser rod. A kind of pyrochemical mixture was studied, in which the barium nitrate, rubidium nitrate, and potassium perchlorate were used as the main oxidizer, and the aluminium magnesium alloy as the fuel (in the ratio $\sim$ 33% for Mg_4Al_3)[5]. To this component was added also pulverized magnesium powder replaced 50% alloy powder as fuel. The following chemical reactions take place when the mixture burning:

$$Ba(NO_3)_2 \rightarrow BaO + N_2 + 2.5O_2, \quad (1)$$

$$2RbNO_3 \rightarrow Rb_2O + N_2 + 2.5O_2, \quad (2)$$

$$KClO_4 \rightarrow KCl + 2O_2, \quad (3)$$

$$2Mg_4Al_3 + 7O_2 \rightarrow 8MgO + 3Al_2O_3, \quad (4)$$

$$2Mg + O_2 \rightarrow 2MgO. \quad (5)$$

The fourth and fifth reactions are highly exothermic, and some of the products were heated and decomposed to atomic state. The persistent lines of the atomic rubidium and potassium were observed in the flame spectrum. The flame spectrum was achieved by EPP2000 miniature fiber optic spectrometer.

Figure 1 shows the emission spectrum of the chemical mixture and the absorption spectrum of the laser glass (dashed line). The emission spectrum covers most of the absorption bands, especially the band around 802 nm which has higher absorbance (only little less than the band around 583 nm) and Stokes factor[6]. Spectrum matching of pyrotechnic flashlamp radiation (solid line) with Nd glass absorption shown in Fig. 1 is better than the method that uses the chemical mixture to which added small amount of strontium nitrate[7].

Schematic setup of our pyrotechnically pumped phosphate Nd glass laser is shown in Fig. 2. Six symmetrically distributed pyrotechnic flashlamps were used as the illuminator. Each flashlamp consisted of eight loosely pressed pyrotechnic poles. There was a little hole in the middle of pole so that electric wire could drill through and form a cluster. Voltages about 60 V (DC or AC) were required to fire the flashlamps. Tandem wires transported the equal electrical ignition energy to each pyrotechnic pole, thereby all flashlamps detonated simultaneously. The ignition fashion made the best use of the chemical energy released by the pyrotechnic poles, especially for those combusted a little slowly. The Nd glass ($C_{\rm Nd} \approx 3\%$) rod was 100 mm long and 8 mm in

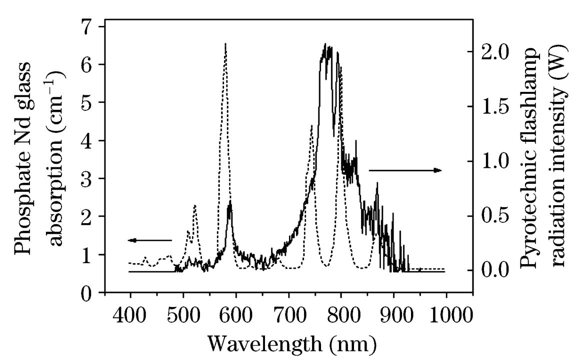

Fig. 1. Absorption spectrum of Nd^{3+} in phosphate glass and the spectral distribution of pyrotechnic mixture.

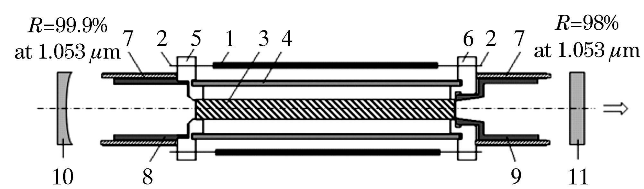

Fig. 2. Schematic of pyrotechnically pumped phosphate Nd glass laser. 1: pyrotechnic flashlamp; 2: electric wires; 3: Nd glass rod; 4: transparent quartz tube; 5,6: teflon brackets; 7: glass tube; 8,9: metallic brackets; 10: concave mirror with high reflectivity at lasing wavelength; 11: output coupler.

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diameter. The rod's side face was dull polished and its both end faces were coated with 1.053 μm anti-reflection films. The transparent quartz tube with 1-mm-thick wall encircled the laser rod. It prevented the lasant from pollution by the smoke and residua of burning. Brackets were used to support the laser rod. The six flashlamps were in series, so certain brackets were made of insulative teflon. The common glass tubes were underpinned by metallic brackets to ensure the insulation. The stable resonance cavity of the laser was formed by a concave mirror ($R = 1$ m) with high-reflection film and a plane mirror as output coupler coated for 98% reflectivity at 1.053 μm.

The time dependence and pulse energy of pyrotechnically pumped Nd glass laser were recorded by a Si photo detector with oscillograph and laser energy/power meter. The 372-mJ laser pulse with 4.56-g pyrotechnic mixture (48 poles and 95 mg each). The relative intensity of laser versus time shown in Fig. 3 presents the whole process of lasing. It shows that the laser power increased quickly and then decreased relatively slowly. Figure 3 also shows that the pulse width of laser was about 68 ms. So the average output power was near 5.5 W, and 50 mV in Fig. 3 corresponded to about 1.8 W can be reckoned.

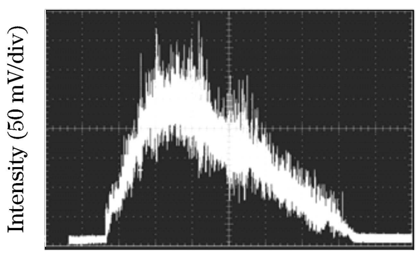

Fig. 3. Relative laser pulse intensity from the oscilloscope.

In conclusion, a pyrotechnically pumped phosphate Nd glass laser with inflammable chemical mixture as pumping source is presented. About 81 mJ/g ratio of laser output energy to pump source weight is achieved. The laser energy and average power could be increased by enhancing the radiation intensity and shortening the burning time of pyrotechnical mixture. The special characteristics of this type of laser save the cubage and weight, so it is suitable in many fields, such as a light source in a long-range synthetic vision system[8] or a beacon light in outer space[7].

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