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# **POTENTIAL OF SOLAR-SIMULATOR-PUMPED ALEXANDRITE LASERS**

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# Potential of Solar-Simulator-Pumped Alexandrite Lasers

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## Abstract

An attempt was made to pump an alexandrite laser rod using a Tamarak solar simulator and also a tungsten-halogen lamp. A very low loss optical laser cavity was used to achieve the threshold minimum pumping-power requirement. Lasing was not achieved. The laser threshold optical power requirement was calculated to be approximately  $626 \text{ W/cm}^2$  for a gain length of 7.6 cm, whereas the Tamarak simulator produces  $1150 \text{ W/cm}^2$  over a gain length of 3.3 cm, which is less than the  $1442 \text{ W/cm}^2$  required to reach laser threshold. The rod was optically pulsed with 200-msec pulses, which allowed the alexandrite rod to operate at near room temperature. The optical intensity-gain-length product to achieve laser threshold should be approximately 35,244 solar constants-cm. In the present setup, this product was 28,111 solar constants-cm.

## I. Introduction

The alexandrite laser has been considered as a candidate for solar pumping and for scaling to high average power for use in space power transmission

applications. This laser system is tunable from 701 to 818 nm at room temperature. The lasing material is the  $\text{Cr}^{3+}$  ion in a host material of  $\text{BeAl}_2\text{O}_4$ . Some of the advantages that have made this an attractive candidate for solar pumping [1] are 40-percent solar-spectrum utilization, 77-percent quantum efficiency, overall solar-to-laser efficiency approaching 14.5 percent, laser tunability in the visible, reasonably long radiative lifetime of 260  $\mu\text{sec}$ , mechanically strong and chemically stable host material, and high average power systems. This laser system has been pumped with flashlamps [2] and mercury or xenon arc lamps [3].

No attempt, to our knowledge, to lase this system using an air-mass-zero (AMO) solar spectrum has been made. Thus, we have attempted to pump an alexandrite laser rod in our Tamarak solar simulator to quantify the laser threshold pumping-power requirement and other laser characteristics.

## II. Experimental Setup

The experimental setup is shown in figure 1. The solar simulator is a continuous wave (cw) high-power xenon arc lamp, and its beam is reflected toward the experiment by a high-quality elliptical reflector. The spectrum emitted by the lamp is similar to an AM0 solar spectrum. A water-cooled shutter is used to produce a pulse of light, approximately 200 msec in duration. The conical collector is used to refocus the simulator light onto an alexandrite rod placed along the

collector centerline. This collector has an entrance diameter of 9.5 cm and an exit diameter of 5.5 cm with an overall length of 9 cm. Figure 2 shows the simulator intensity patterns, using thermal-sensitive paper, at the entrance to the collector and at the exit plane of the collector. The collector effectively concentrates the simulator light to a small spot as shown by the exit plane burn pattern. Also shown is the intensity pattern along the collector Z axis. These profiles indicate that the pumping-light volume is approximately 4-cm long by 0.2 cm in diameter. An intensity profile on the axis had been previously taken and is shown in figure 3 [4]. The full-width-half-maximum (FWHM) pumping intensity in solar constants is approximately 9000 over a 3.3-cm distance, which is close to the 4 cm shown in the burn profile of figure 2.

A high-quality alexandrite rod, borrowed from Allied Corporation, has dimensions of 4-mm diameter by 107-mm length with anti-reflection coatings on the rod ends. This rod was placed in the center of the concentrator pumping intensity profile. This resulted in only pumping approximately 4 cm of the 10-cm long alexandrite rod. The unpumped regions of the rod could absorb at the laser wavelength, causing additional cavity optical loss and thus increasing the laser threshold pumping power. After consultation with Allied Corporation,

this loss was found to be very small at the laser wavelength (order of 1 percent at 760 nm). Thus, this does not appear to be a significant problem.

A low loss optical cavity was placed around the rod consisting of a back mirror of 0.05-percent transmission and an output mirror of 0.3-percent transmission at 760 nm. These mirrors were aligned with both a He-Ne laser and an autocollimator.

A typical simulator light pulse is shown in figure 4. The upper trace shows the optical fluorescence from the alexandrite rod as detected by a silicon detector (laser detector). The lower trace is the optical illumination from the simulator. The single-pulse mode of operation was used in order to minimize the heat loading of the alexandrite rod. No additional cooling was used. After a typical pulse, the rod did not rise more than 5° C above room temperature.

### III. Laser Threshold Pumping-Power Calculations

Figure 3 shows the Z axis dependence of the collector optical power. At the peak, the optical power is 2300 W/cm<sup>2</sup> at 600 amps arc current. The radial dependence can be seen from figure 2, which indicates a 0.1-cm radius at FWHM intensity. Thus, the optical power incident on the Alexandrite rod is

$$P = (2.3 \text{ kW/cm}^2) (2\pi) (0.1 \text{ cm}) (3.3 \text{ cm}) = 4.7 \text{ kW} \quad (1)$$

From the paper by Weksler and Shwartz [1], the laser threshold pumping

intensity was calculated to be  $626 \text{ W/cm}^2$  (4637 solar constants) for a 7.6 cm-long rod with a 6-mm diameter. This intensity is shown by the dashed line in figure 3. In our solar simulator, the optical intensity is  $1150 \text{ W/cm}^2$  with an excitation length of 3.3 cm. To derive the solar simulator power requirement for laser threshold, we set up the following proportion between Weksler's and Shwartz's calculation, and our simulator setup as

$$(626 \text{ W/cm}^2) (7.6 \text{ cm}) = P_{\text{th}} (3.3 \text{ cm}) \quad (2)$$

$$P_{\text{th}} = 1442 \text{ W/cm}^2 \quad (3)$$

This is the equivalent incident optical intensity requirement needed from our solar simulator to achieve laser threshold. This intensity indicates that the potential for lasing in the solar simulator is problematic, since as stated earlier, the available similar optical intensity is only  $1150 \text{ W/cm}^2$ .

An approximate estimate of the laser threshold is the product of gain length and threshold solar constants. Weksler and Shwartz's calculation suggests that this product should be 35,244 (s.c.-cm). For the present Tamarak setup, this product is only 28,111.

#### **IV. Laser Experiments**

Experiments were initiated to determine laser threshold using an AMO solar spectrum as the pumping source. All optical cavity losses were minimized in order

to achieve the lowest possible laser threshold pumping-power requirement. The simulator arc current was run at the maximum of 600 amps to maximize the optical input. The laser cavity was carefully aligned with both a He-Ne laser and an autocollimator.

Approximately 50 attempts to lase the alexandrite rod were made. No indication of lasing was observed, indicating that the laser was below threshold for the geometry and optical illumination power ( $1150 \text{ W/cm}^2$ ) of the present experiment. The previous calculation would indicate that at least  $1442 \text{ W/cm}^2$  would be needed from the solar simulator using a gain length of 3.3 cm.

In order to further investigate the potential of lasing alexandrite under a very different laser geometry, we used a CVI (C-95) YAG Max laser system as a pumping source for the same alexandrite laser rod that was used in the solar simulator. Also, the same laser cavity mirrors were used. This laser system uses two 3200-K tungsten-halogen lamps in a high-quality optical reflector to pump the laser rod. The electrical power to the lamps was 1500 W, and the optical pumping length of the alexandrite rod is 5.7 cm.

Lasing was not observed at any time using this system. Using equation (2) again would give an optical-intensity requirement of  $835 \text{ W/cm}^2$ , which is above the



105 W/cm<sup>2</sup> lamp intensity (even assuming 100 percent electricity-to-light conversion).

## **V. Conclusions**

Solar pumping of alexandrite lasers will require significantly greater optical pumping power than present iodine or YAG laser systems. For the two systems used to pump alexandrite (a xenon arc and a tungsten-halogen lamp) laser threshold was not reached. The approximate threshold pumping-intensity requirement is the product of solar constants times gain length and should be above 35,244 (s.c. - cm). The Tamarak solar simulator intensity-gain-length product was only 28,111 solar constants-cm. Future studies of alexandrite should use optical sources that can produce at least twice the threshold requirement.

## **VI. Acknowledgements**

The loan of alexandrite rods from Allied Corporation and technical discussions with Don Harter are gratefully acknowledged.

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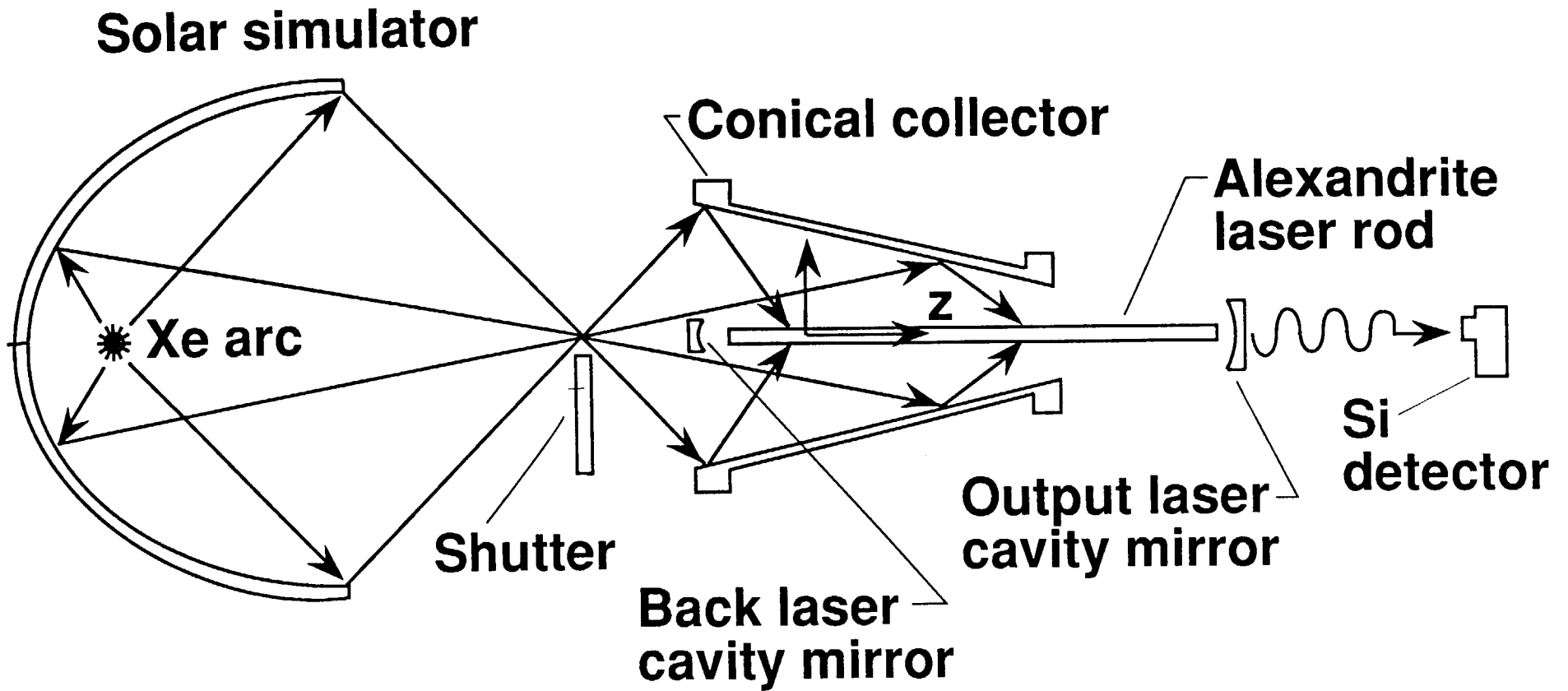


Fig. 1. Tamarak solar simulator setup for pumping alexandrite laser rod.

# SOLAR SIMULATOR INTENSITY PATTERNS

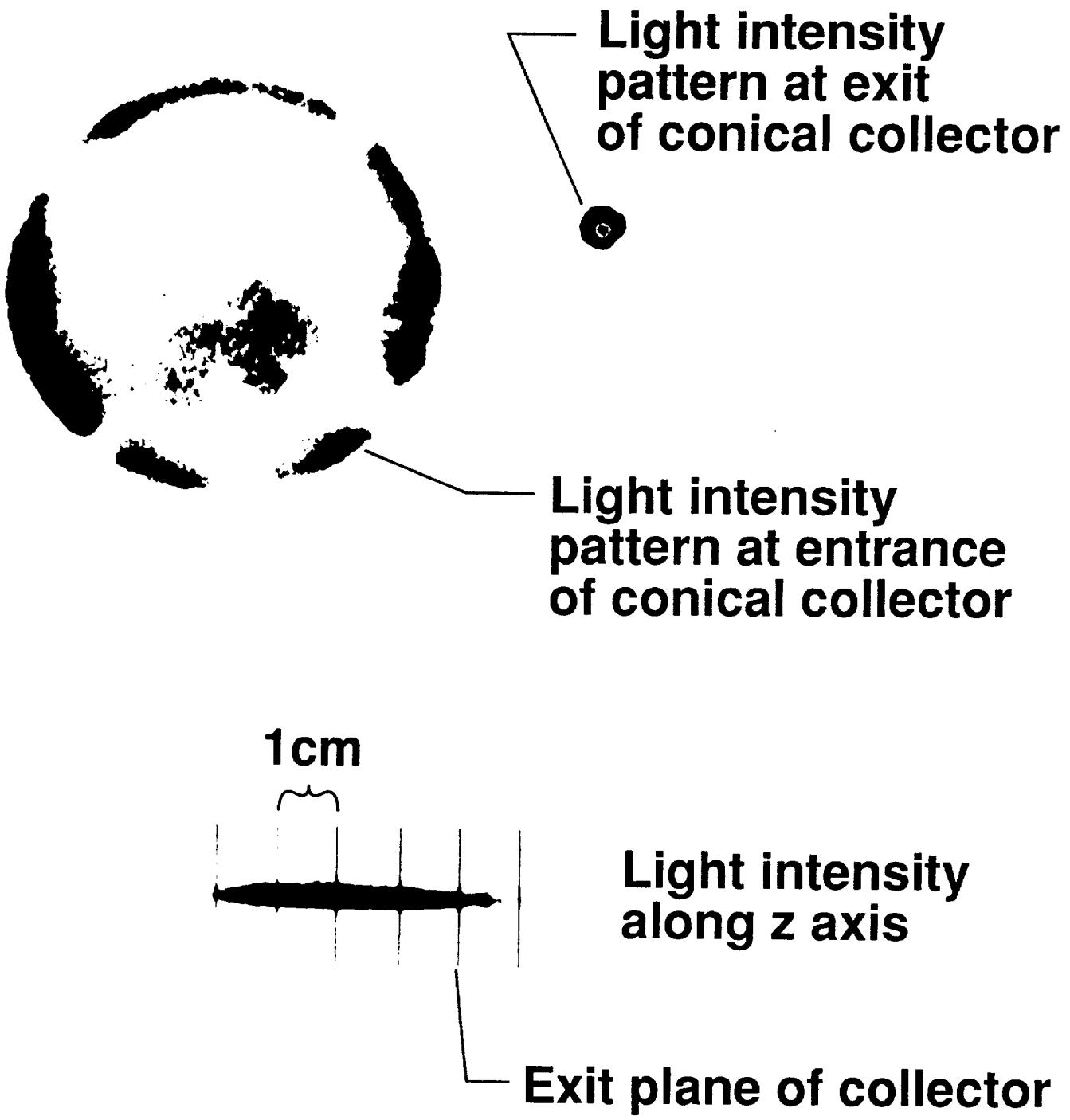


Fig. 2. Tamarak optical burn patterns.

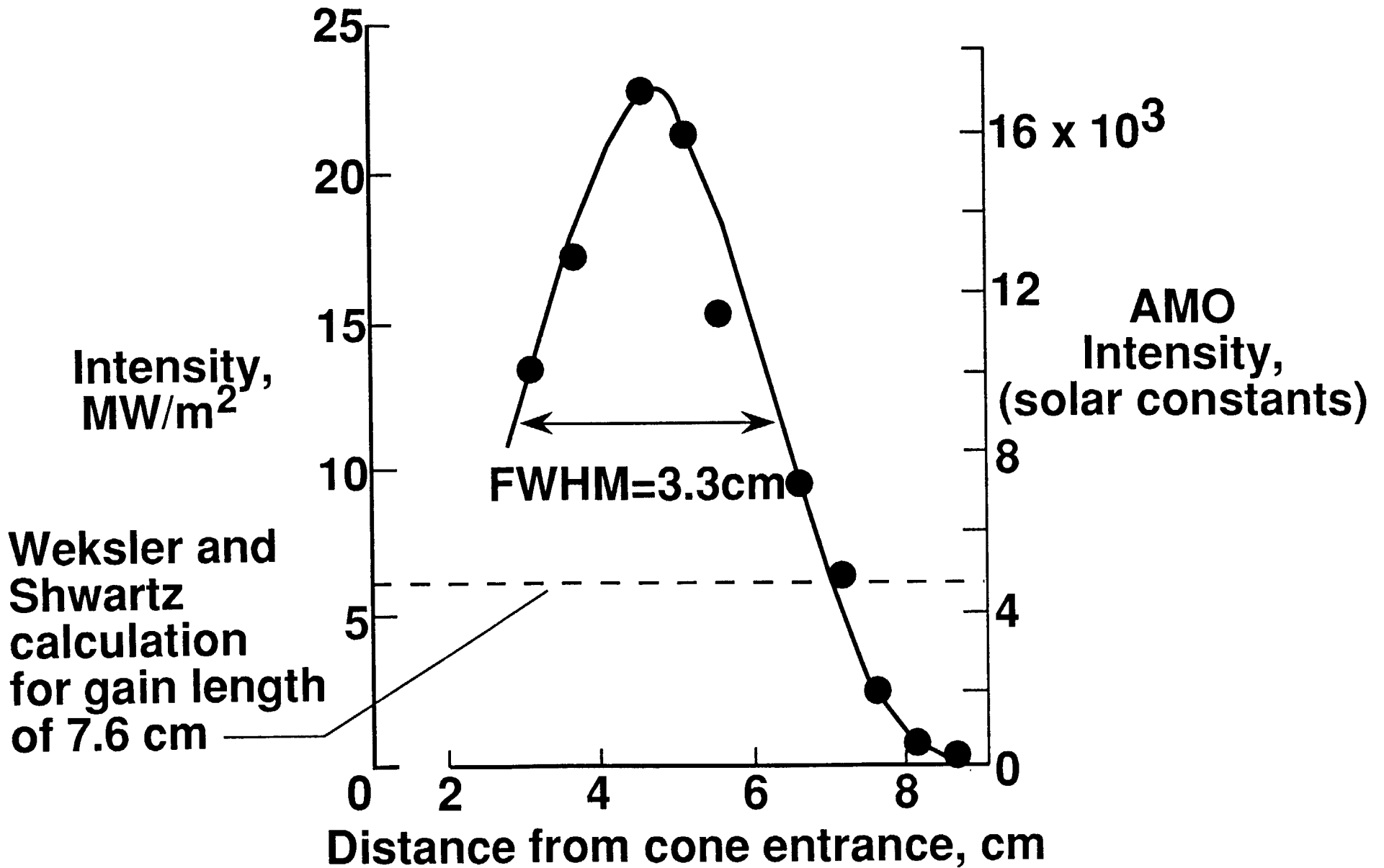


Fig. 3. Tamarak optical intensity along the Z axis.

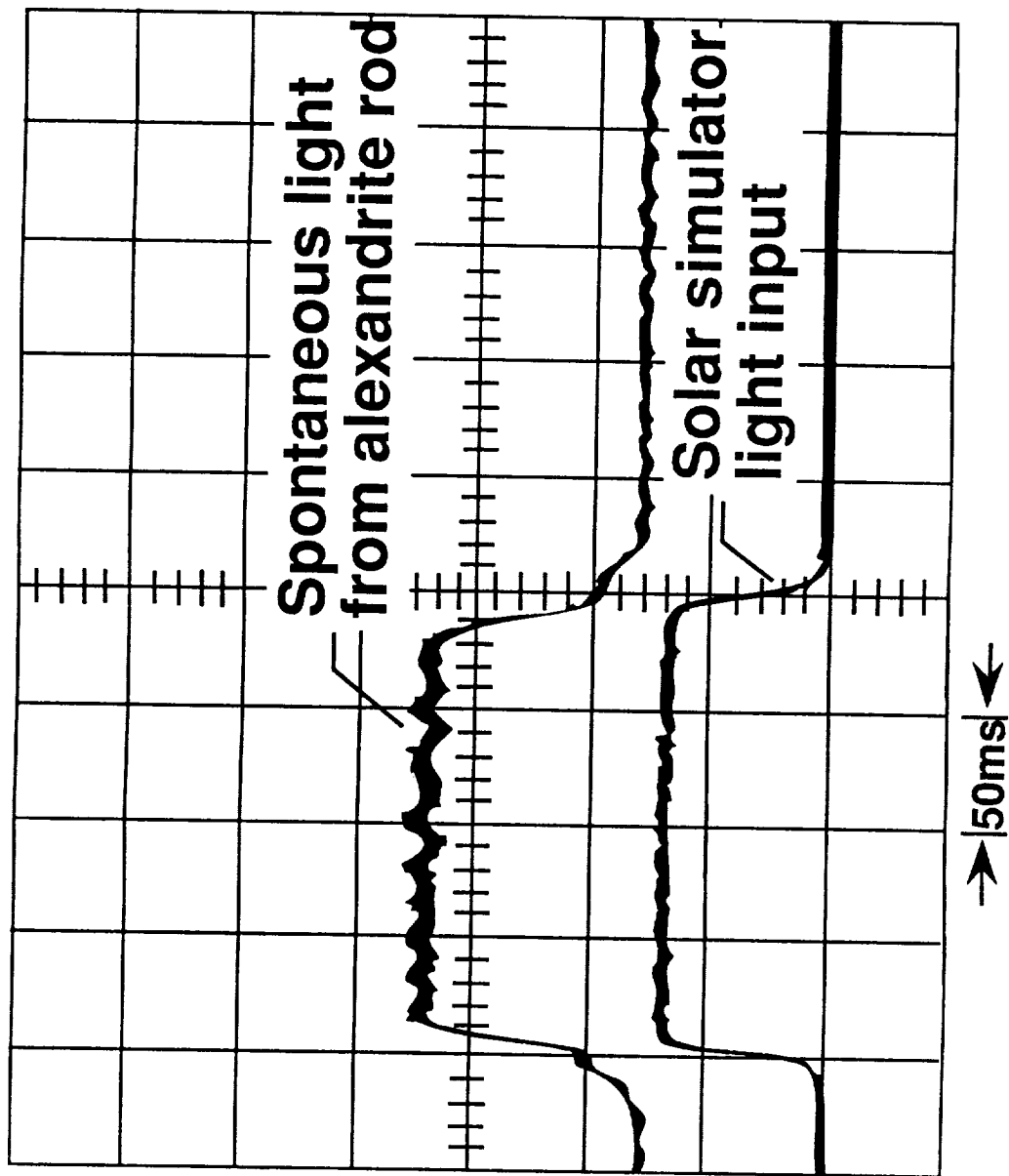


Fig. 4. Spontaneous emissions from alexandrite laser rod and solar simulator light input pulse.



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