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INTERMEDIATE PULSEWIDTH LASER SYSTEM

Semiannual Technical Report No. 5

1 April 1968 - 30 September 1968

Contract No. N00014-66-C-0056
ARPA Order No. 306

Prepared by
Central Research Laboratory
American Optical Corporation
Southbridge, Massachusetts 01550

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13. ABSTRACT

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1. INTRODUCTION

The purpose of this program is to design and construct a glass laser system capable of providing high energy spike-free output in square pulses of 1, 3, 10, 30 and 100 microsecond lengths. The output beamspread is to be two milliradians or less.

The contract work was split into two phases. Phase one was to study feasibility of such a system and was reported in Semiannual Technical Report No. 1. Phase two is to design, construct and deliver a system based on the findings in Phase one.

The design of the system was discussed in Semiannual Technical Report No. 1. The principle of operation is to provide amplified spontaneous emission with a generator rod or rods. This emission is smooth in output, i.e., spike-free, and typically under high-gain conditions, has a duration of 250-300 microseconds full width at half height. At the peak generator output a Kerr cell is switched to provide a square pulse of amplified spontaneous emission. The Kerr cell output is then fed into a preamplifier to further increase signal intensity to drive the final amplifiers. The total output from the combined final amplifiers is to be 1000 joules. If pulse sharpening occurs, the ramp generator can be employed to offset this pulse deformation and provide a square wave output pulse.

The system beamspread is controlled by the overall length of the system and the use of afocal telescopes. The diameter of the final amplifier divided by the overall length of the system is the aspect ratio. This determines the minimum beam divergence that can be obtained without the use of afocal telescopes. Because the rods used in the generator section have a smaller diameter than the preamplifier, an afocal telescope will be used to expand the beam from the generator to match the preamplifier cross section. This reduction of beam divergence will also help to overcome a degradation of beamspread due to thermal distortion in the preamplifier. A second afocal telescope used between the preamplifier and the final amplifiers will help in further reduction of the beam divergence as well as provide an expanded beam diameter. This expanded beam will be large enough in diameter to allow the final amplifier to be clustered within the beam profile and thus make maximum use of the preamplifier output.

2. IMPLEMENTATION OF SYSTEM MODIFICATIONS

Modifications to the laser system were discussed in Semiannual Technical Report No. 4, and were implemented during this time period. The first of the modifications was to change the third generator rod to an 18 mm by 1 meter rod doped with 2 wt% Nd_2O_3. The rod was dry ended but clad with a ten percent aqueous solution of $NaNO_3$. To prevent surface damage at the periphery of the rod, an aperture stop was installed at the input end that restricted the beam diameter to 15 mm. The gain versus pump input curve is shown in Figure 1. A maximum gain of 29.5 dB was measured for a pump input of 24 kilojoules in a 2 millisecond pump pulse.

Fabrication of parts for a Faraday rotator and a capping shutter to be used at the output end of the third generator rod was completed. These units, however, were not installed because of time limitations and also because it was not necessary for the operation of the system in this laboratory. They will, however be installed when the system is delivered.

A 2x afocal telescope was designed to couple the third generator rod to a fourth generator rod which was fabricated and installed. The fourth generator rod was fabricated to insure sufficient signal output from the preamplifier. This rod is 3.8 cm in diameter and has a doping concentration of 1.1 wt% Nd_2O_3 to provide uniform pumping over a 3 cm cross section. The gain versus pump input data is given in Figure 2 which shows a gain of 11.4 dB for an input of 23.5 kilojoules. The rod was pumped with four EG&G FX-47 lamps with 46 cm arc lengths. The overall length of the rod was 62 cm.

A double-doped preamplifier rod was fabricated with a doping concentration of 2 wt% Nd_2O_3 and 3 wt% Yb_2O_3. The reasons for this doping concentration were discussed in Semiannual Technical Report No. 4. The gain versus pump input for the rod was measured using a two millisecond pump pulse. Four flashlamps were used in a close-wrap configuration. A gain of 14.8 dB was measured with a flashlamp pump input of 48 kilojoules as indicated in Figure 3.

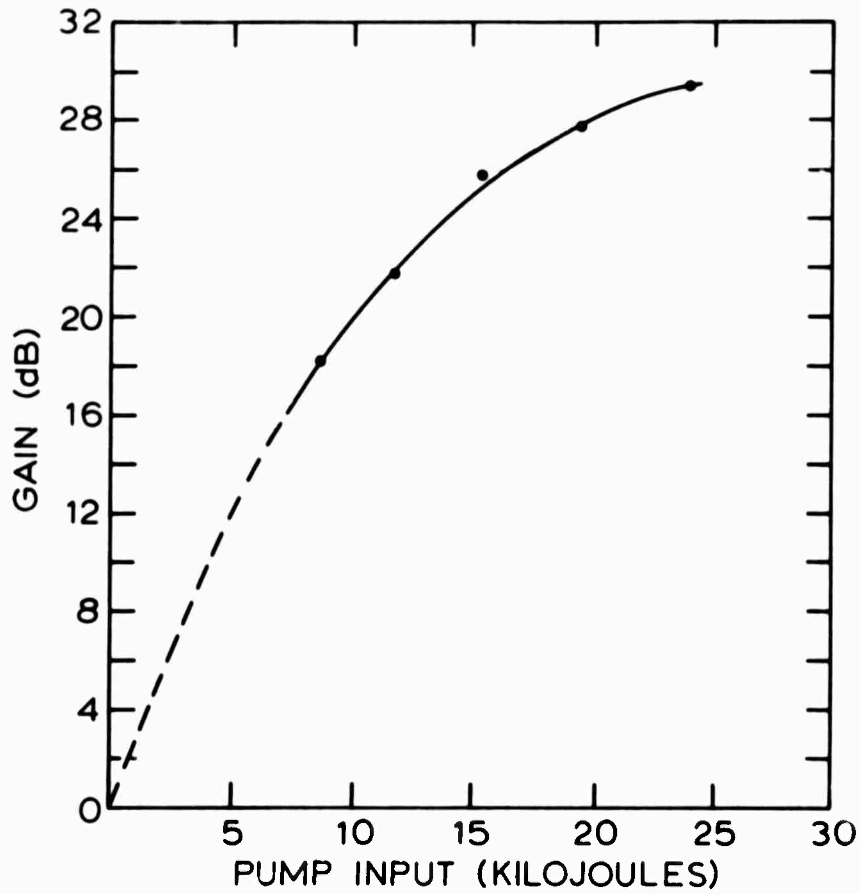


Figure 1. Small signal gain of 18 mm x 1 m rod doped with 2 wt% Nd_2O_3 as a function of pump input. Pump duration 1 ms, pumped length 85 cm.

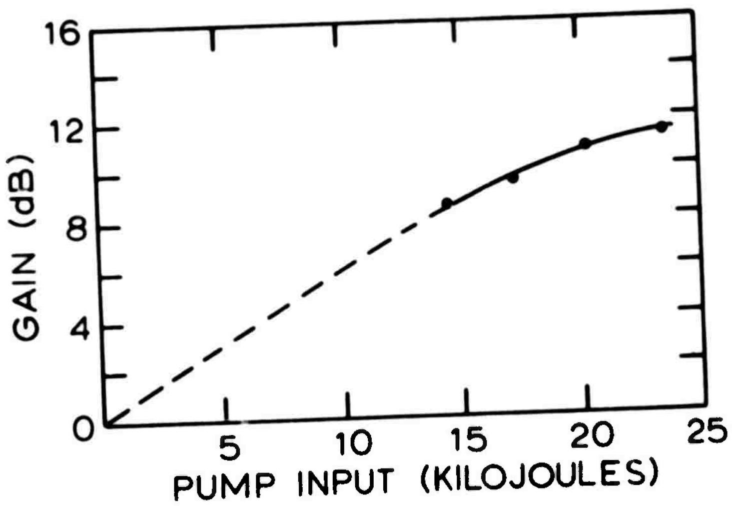


Figure 2. Small signal gain of 3.8 cm x 62 cm generator rod doped with 1.1 wt% Nd_2O_3 as a function of pump input. Pump duration 1.2 ms, pumped length 46 cm.

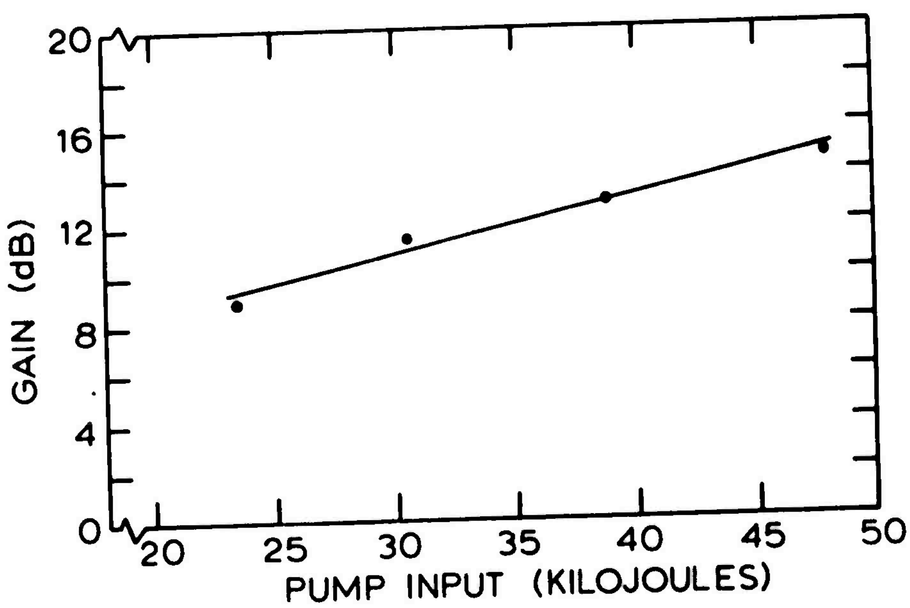


Figure 3. Small signal gain of double doped 3 cm x 1 m pre-amplifier doped with 2 wt% Nd_2O_3 + 3 wt% Yb_2O_3. Pump pulse 2 ms, pumped length 85 cm.

Experimental glass melts were made to obtain a durable glass with a Verdet constant as high as, or higher than commercially available glasses for use as a Faraday rotator element in the final Faraday rotator positioned between the preamplifier and final amplifiers. A glass with a Verdet constant of 0.038 at 1 μm was developed. The sample length for the Faraday rotator will have to be 11.4 cm for a 45 degree rotation. Samples of the glass were tested with a one microsecond pulse and have withstood 80 J/cm^2 with no internal damage. This glass may also be used for the collector lens at the output end of the system.

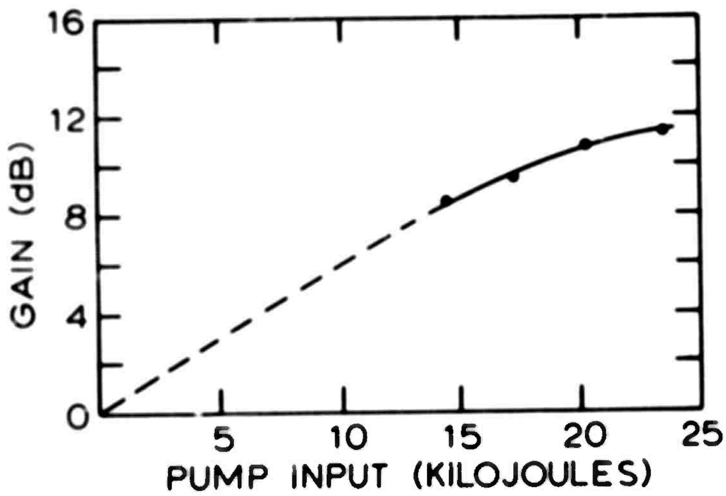
3. SYSTEM PERFORMANCE

The complete generator section consisted of four generator rods, the fourth generator being the 3.8 cm diameter rod described in the previous section of this report. An output of 20 joules in a 1 microsecond pulse was obtained with a square waveform from this section. This was enough to drive the preamplifier and produce an output of 207 joules in a 1.5 microsecond pulse. At this energy level two damage sites appeared at the output end in an unpumped region. Because the damage was very near the end of the preamplifier, the rod was shortened by cutting off the damaged portion and refinished. It was used in the system again and a damage site was produced near the edge of the rod at the output end at an energy level of 105 joules in 1 microsecond. The input end of the preamplifier was stopped down with an aperture stop to reduce the beam size from 3 cm to 2.7 cm thus preventing laser energy from impinging upon the damage site. After this was done, over a dozen shots were taken at energy output levels between 90 and 101 joules with no further damage to the rod.

During this time period, and before the fourth generator rod was installed, the system was also operated to obtain pulses with a square waveform for pulsewidths of 3, 10, 30 and 100 microseconds. The ramp function built into one of the Kerr cell driver units proved very effective in overcoming pulse sharpening.

4. THRESHOLD DAMAGE Vs. PULSEWIDTH FOR SCHOTT SF-4 OPTICAL GLASS

A series of experiments was undertaken to obtain information on the threshold for inclusion damage in high optical quality glass as a function of pulse duration. The glass used was



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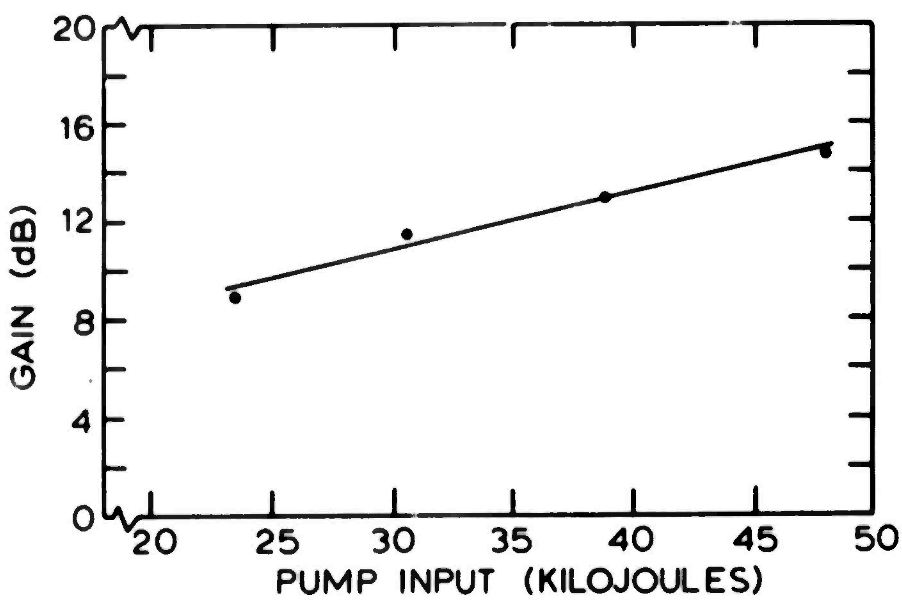

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Schott SF-4 high index glass of excellent optical quality made in platinum crucibles. No particles could be seen in this glass under microscopic cross-illuminated examination. The damage thresholds were measured for pulse durations of 0.03, 1, 10, and 50 microseconds. The 0.03 microsecond pulse was produced by a normal Q-switched laser producing a triangular-shaped pulse. All the other pulses were produced with this device. The thresholds for damage are tabulated in Table I and plotted in Figure 4.

TABLE I. THRESHOLDS FOR DAMAGE

Pulse Duration in Microseconds	Damage Threshold in J/cm^2
0.03	20
1.0	27 - 30
10.0	47 - 60
50.0	150 - 200

The information obtained from this experiment was for a particular glass (Schott SF-4) and a particular melt of this glass. It does not mean that the same damage threshold will be found for other glasses or even different melts of the same glass.

5. MODIFICATIONS TO THE SYSTEM AND DELIVERY

During this reporting period, Dr. F. Quelle of ONR, Dr. P. Avizonis and Dr. R. Rudder from Kirtland AFB came to American Optical Corporation to discuss progress made in developing this laser device. After a detailed discussion of all the problems involved, it was decided to ship the laser system to Kirtland AFB. The system can provide output energy from the preamplifier in the range 90 - 100 J repeatedly and this, it was felt, was enough to get experiments started at Kirtland AFB.

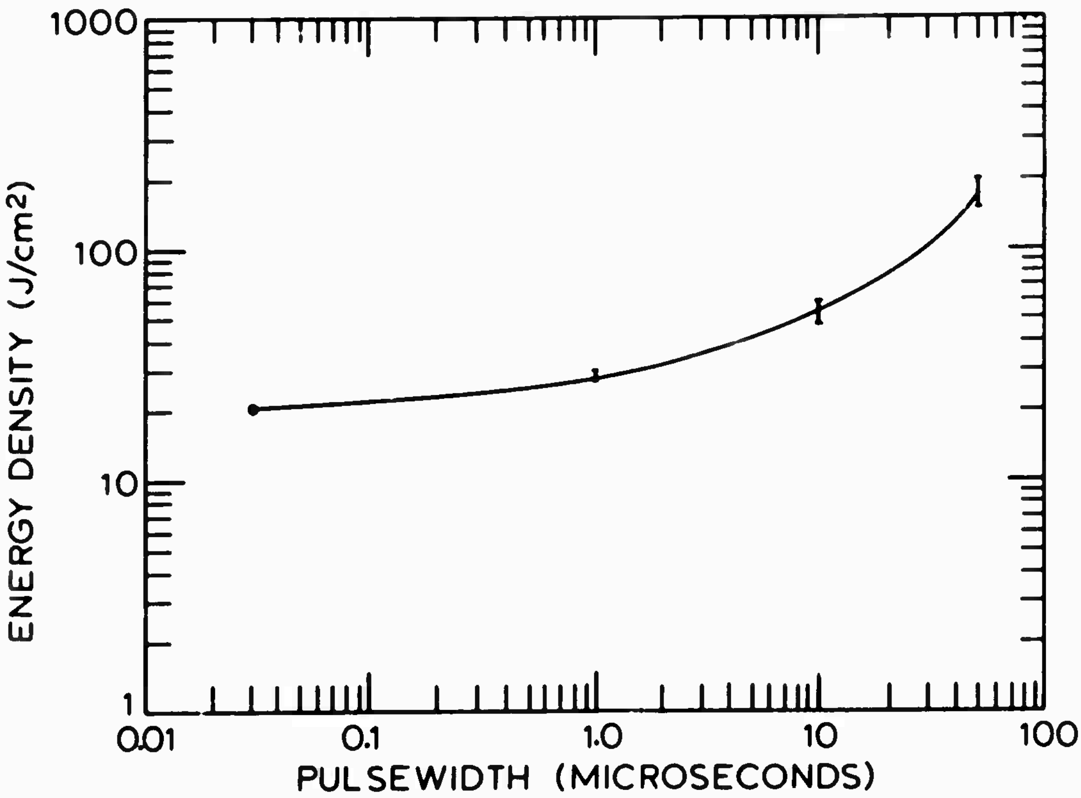

Figure 4. Threshold for damage to Schott SF-4 glass as a function of pulse duration.

In the meantime, the final amplifier design will be modified. The four final amplifier rods, that had a cross-sectional area of 28 cm^2, will be changed to two rods with each rod being approximately 7.5 cm in diameter and having a useful total cross-sectional area of 66 cm^2. This means that instead of 35 J/cm^2 required from the four-amplifier arrangement only 15 J/cm^2 will be required with the two 7.5 cm diameter amplifiers. With a preamplifier output of 50 joules, the gain required in each of the two final amplifiers would be in the range of 18 dB to obtain a final output of 1000 joules. Gains of 13 - 14 dB have already been measured in amplifiers of this size at pump inputs of 80 kilojoules.

There would also be a change in the type of laser glass used in the new amplifier arrangement. Whereas the original specifications required that the four final amplifiers had to be double-doped laser glass (Nd_2O_3 + Yb_2O_3) to prevent pulse sharpening, the modification using two large diameter amplifiers will only require Nd_2O_3 doping. This is because at an output of 15 J/cm^2 only 3 - 4 dB of pulse sharpening is anticipated and this can be corrected by using the ramp function of one of the Kerr cells.

Figure 5 is a schematic of the device layout. It shows that beamsplitters are required to couple the preamplifier to the two final amplifiers. Tests were conducted on the durability of the beamsplitters, that showed they were durable to at least 8 J/cm^2 in one microsecond. Many shots were taken at energy densities ranging between 5 and 8 J/cm^2 with no damage evident. In actual use the beamsplitters need to be durable at energy densities of 0.5 to 1 J/cm^2.

During this report period the system was dismantled and shipped to Kirtland AFB. The arrangement was made to have a technical representative go to Kirtland AFB to assemble and align the laser device whenever the personnel at the air base are ready to have this done.

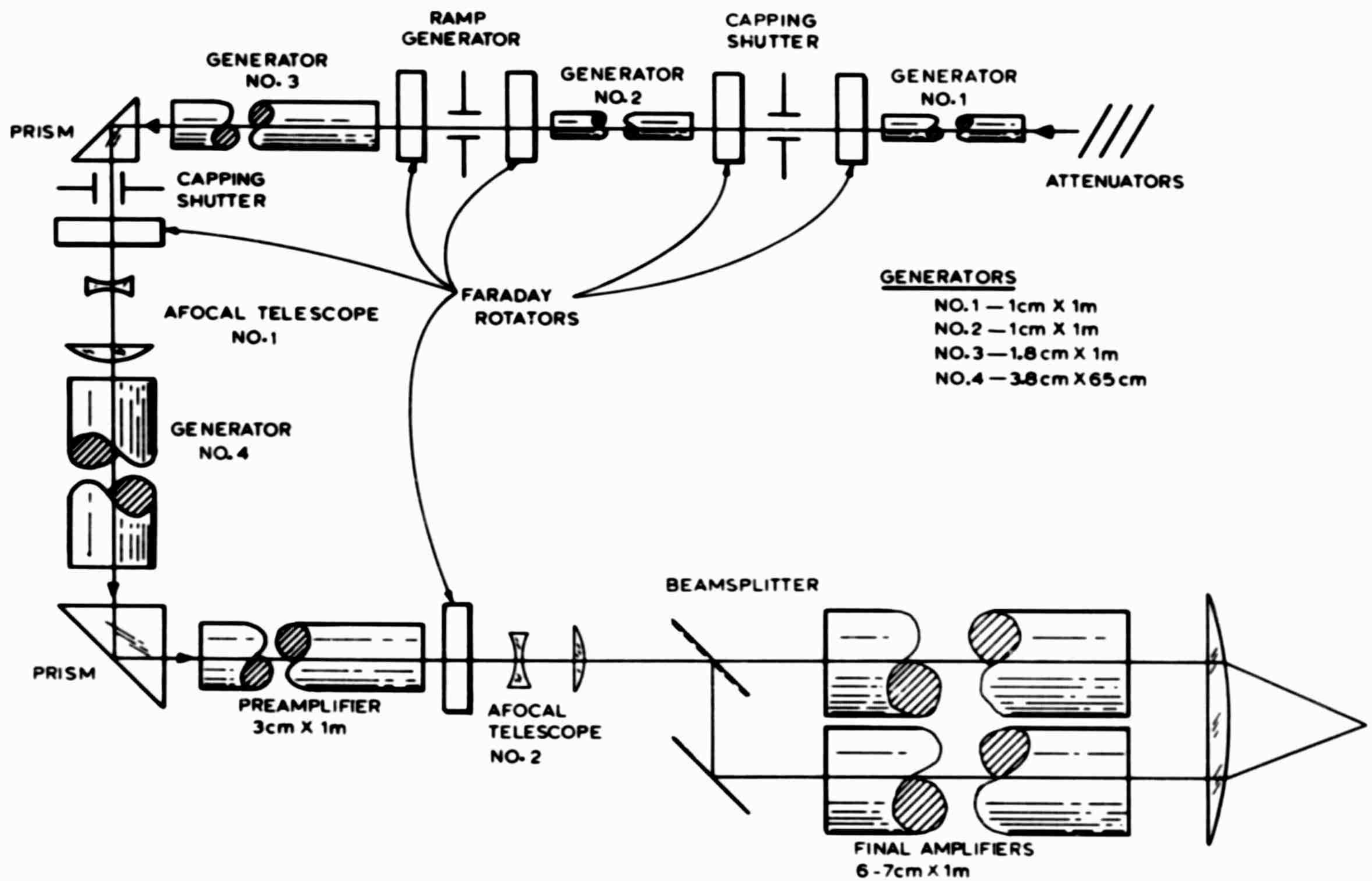

Figure 5. Schematic of the device layout with proposed changes.