NRL Report 6181

Comparison of Underwater Attenuation of Laser With Nonlaser Light

G. L. Knestrick, J. A. Curcio, and A. G. Rockman

Radiometry Branch
Optics Division

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U.S. NAVAL RESEARCH LABORATORY
Washington, D.C.

ABSTRACT

In a cooperative effort with the U.S. Naval Ordnance Laboratory, the attenuation coefficients of filtered Potomac River water were measured for coherent and for noncoherent light. A He-Ne gas laser served as a source of coherent red light at 6330A, and a filtered, collimated, concentrated arc lamp furnished noncoherent light at 6355A (red) and at 5255A (green). The divergence of the light beam was of the order of one milliradian in all cases, and the entire cross section of the beam was always accepted by the receiver. The attenuation of red light was measured for underwater ranges of 6 to 36 m and of green light for ranges of 6 to 122 m. No experimentally significant difference was found between the attenuation coefficients measured for coherent and noncoherent light. The value obtained at 6328A was 0.35 m^{-1}, and at 5255A the value was 0.097 m^{-1}.

PROBLEM STATUS

This is a final report on one phase of the problem; work is continuing on another phase.

AUTHORIZATION

NRL Problem N01-07
Projects RR 002-10-45-5058
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COMPARISON OF UNDERWATER ATTENUATION OF LASER WITH NONLASER LIGHT

INTRODUCTION

The advent of lasers restirred interest in the propagation of light in water and led to some investigations of the transmission of ruby laser light and of "ordinary" green light through water (1,2). More recently there has arisen some speculation that laser light is in some way different from nonlaser light in its propagation properties and that underwater attenuation is less for laser light than for nonlaser light of the same wavelength. This seems highly unlikely in the absence of "hole burning," but it recently became possible to investigate this briefly. The attenuation coefficients of filtered Potomac River water were measured for the red radiation from a gas laser and for similar red radiation from a filtered miniature arc light. Coefficients were also remeasured for green light from a filtered arc light in order to compare them with the coefficients being measured by the U.S. Naval Ordnance Laboratory for green* laser radiation in the same water.

EQUIPMENT

The study was carried out at the David Taylor Model Basin, Carderock, Md., in a manner similar to the previous study (1,2).

The projector periscope system (Fig. 1), which projected the light beam at a depth of 2.1 m below the water surface, was the same system used in the earlier study (2). The source of laser light was a 1-mw He-Ne gas laser with a beam divergence of less than a milliradian. Nonlaser light was furnished by a 25-w zirconium arc lamp which was collimated by an f/13 lens of 20-in. focal length into a beam which diverged approximately one milliradian.

When the laser source of red radiation (6328A) was used, an interference filter was inserted in the projector periscope to reject pump light. The half bandwidth of the filter was 6.5A and the peak wavelength for normally incident light was 6336A. A second interference filter with a 100A halfwidth and a center wavelength of 6330A was used in the receiver to prevent background light in the water from reaching the detector.

The arc light was filtered at both wavelengths with two interference filters, one in the projector and one in the receiver. The passband of the combined red filters was centered at 6355A and had a halfwidth of 80A. The peak wavelength of the combined green filters was 5255A and the halfwidth was 85A. Transmission at visible wavelengths outside the passband of a single filter, red or green, was less than 0.1 percent.

The receiver consisted of the same 12-in.-focal-length f/2.5 lens used previously (2), a variable field stop, and a detector. The field stop was normally 1/2 in. in diameter; hence, the angular field of view (in water) of the receiver was 1.8 degrees. The effect of varying the field of view was also studied with angular fields of 0.45 and 0.9 degree, established by the insertion of other circular stops.

The detector used for all attenuation measurements was an RCA 7265 14-stage multiplier with an S-20 response, operated at 2000V. To prevent multiplier saturation at close

*The laser used for this purpose was a frequency-doubled neodymium glass (infrared) laser.

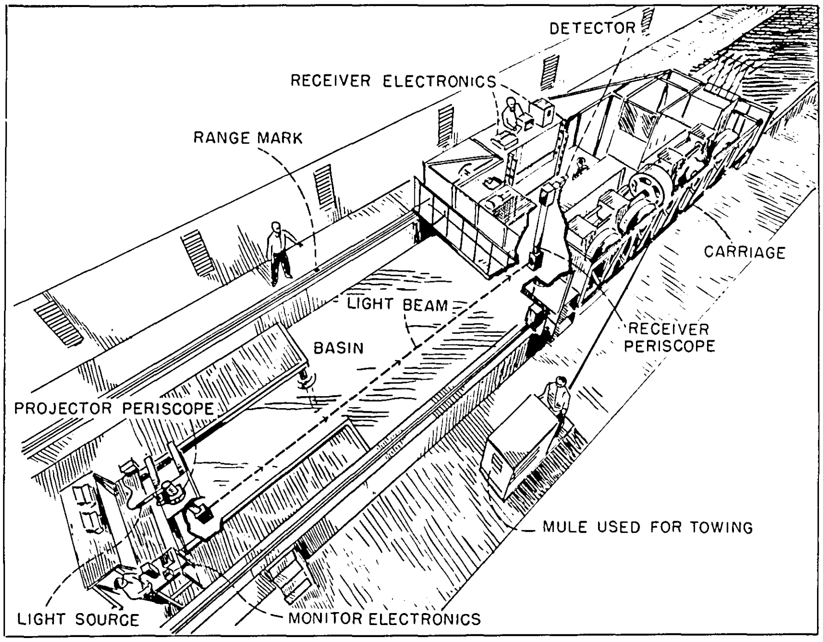

Fig. 1 - Diagram of experiment installed in model basin

ranges, the light was attenuated by an evaporated metal film type of neutral filter inserted in the receiver. The multiplier signal was fed directly into an oscilloscope.

Light from the source was modulated at 120 cps by a motor-driven chopper. A small portion of this light was deflected by a beam splitter to a monitoring detector, a type 6342 (S-11) photomultiplier, the output of which was amplified, rectified, and recorded on an Esterline-Angus recorder. Power for the light sources, monitor amplifier, and receiver oscilloscope was stabilized by electronic voltage regulators.

A complete series of attenuation measurements at both the red and green wavelengths was made with the water continuously circulating through the filtration system, which consisted of two batteries of four filters each, filled with gravel and Neutralite (crushed marble). The rate of flow through the filter was 2000 gal/min. The green measurements were later repeated after the circulation had been shut off for a period of time.

RESULTS WITH RED LIGHT

The relative transmission of red laser light (6328A) was measured at 6.1-m projector-to-receiver intervals, starting at a separation of 6.1 m and going up to 36.6 m. Although the equipment carriage could have been motor-driven, starting the motor would have produced heavy vibrations which could have destroyed the periscope alignment. For this reason, the carriage was towed from one position to the next with an electric "mule," as shown in Fig. 1.

Signals were read directly from the oscilloscope and corrected for the transmission characteristics of any neutral filter used. The logarithms of the corrected signals are shown plotted as a function of the underwater range in the curve marked "coherent" in Fig. 2. The attenuation coefficient σ, yielded by the least-squares slope of the straight line best fitting the data points, is 0.358 ± 0.006 m^{-1}.* The curve marked "noncoherent"

*Plus or minus values in this report represent the 95% confidence limits, i.e., 2.2 standard deviations

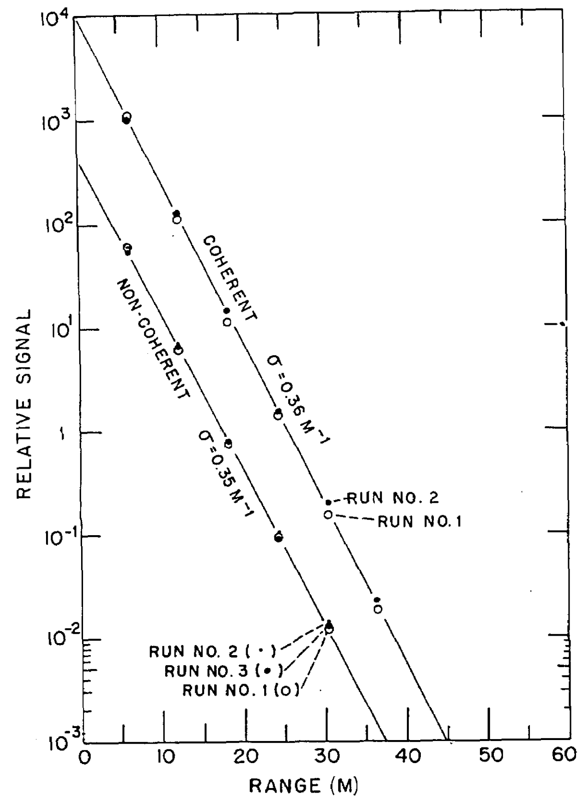

Fig. 2 - Relative transmissivity at 6330A for filtered Potomac River water as measured with a coherent He-Ne gas laser and a noncoherent concentrated arc light source

in Fig. 2 represents the data obtained with red arc light (6355A) for water path lengths of 6.1 to 30.5 m and yields a σ value of $0.347 \pm 0.005\ m^{-1}$. Therefore, the coefficients for red laser and nonlaser light agree within the limits of experimental error and, further, the value obtained is approximately what one would expect based on the previous study of Potomac River water.

The attenuation coefficients measured in the earlier study (2) are plotted in Fig. 3 along with the above value for 6330A light. Included for comparison is Hulburt's curve for distilled water (3).

RESULTS WITH GREEN LIGHT

The relative amount of green (5255A) noncoherent light transmitted through the water was measured, by personnel of this Laboratory, at intervals of 12.2 m from 12.2 to 122 m on three runs. On another run, an additional measurement was made at 6.1 m. The data, plotted in Fig. 4, give a value for σ of $0.097 \pm 0.001\ m^{-1}$ at 5255A for filtered water. This is in good agreement with the value of $0.099\ m^{-1}$ obtained at this wavelength in the previous study (2).

Separate measurements with coherent green laser light were made by the U.S. Naval Ordnance Laboratory, White Oak, Md., using the same periscope system; their results are in agreement with the NRL results and will be published in NOL Technical Report 64-179.

The attenuation of noncoherent light at the green wavelength was again measured after the coherent green light measurements had been completed. The water had not been filtered for six days. The data obtained on two measurement runs are plotted in Fig. 5

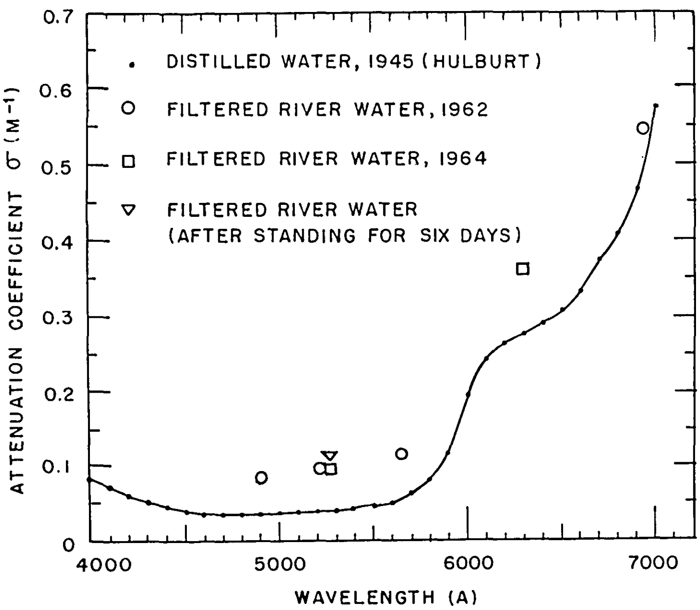

Fig. 3 - Spectral attenuation coefficients of Potomac River water obtained in this study (1964) and in previous study (1962). Included for comparison are Hulburt's data (1945) for distilled water (Ref. 3).

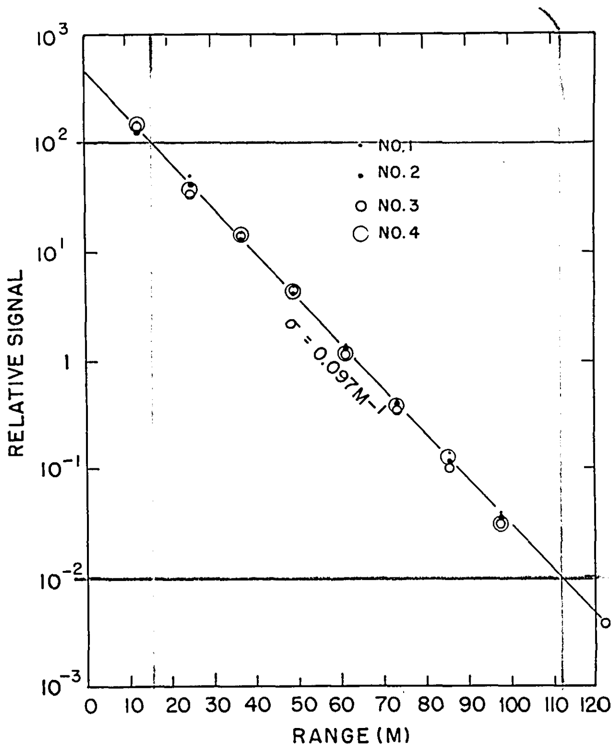

Fig. 4 - Relative transmissivity at 5255A for filtered Potomac River water as measured with a noncoherent light source

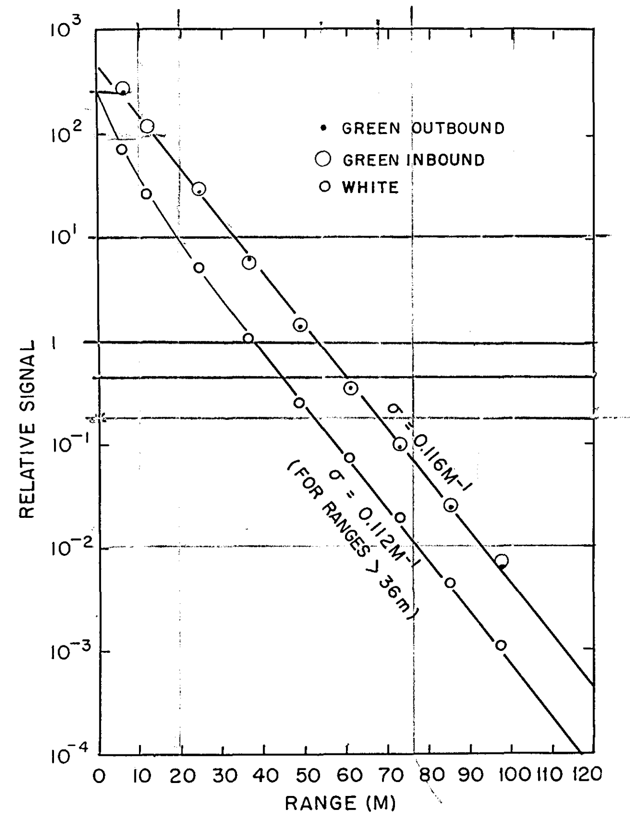

Fig. 5 - Relative transmissivity of filtered Potomac River water after standing for six days. Upper curve is for measurement at 5255A with noncoherent light; lower curve is for noncoherent, unfiltered white light. The two curves are not relative to each other.

from which an attenuation coefficient of 0.116±0.001 m^{-1} was obtained, a 20-percent increase over the coefficient for continuously filtered water. The results of the NOL measurements which had been made in the intervening five days, showed a steadily increasing attenuation during that period and agreed with the above data, to within three percent, on the amount of change that took place.

The attenuation of white light, that is, unfiltered arc light, was measured immediately after the last noncoherent green light measurement. The data are also plotted in Fig. 5 and show a coefficient changing with range out to 36 m, beyond which the coefficient does not change and has a value (0.112 m^{-1}) slightly less than that for 5255A light. It should be made clear that the signal values plotted for the latter curve are relative and should not be compared to the signals shown for green light.

An effort was made to determine whether scattered light in the water was contributing to the measured signals. The angular field of view was decreased from the normal 1.8 degrees to 0.9 degree at various distances in both red and green light measurements and, in one instance, the angular field was reduced to 0.45 degree, but there was no consistent effect on the signal.

CONCLUSION

The results indicate that, as expected, filtered river water attenuates laser light and nonlaser light equally. The method of measurement appears to be reliable since the coefficient value obtained for green light in this study agrees with that measured at the same wavelength in another study conducted two years ago. The attenuation coefficient measured at 6328A was 0.35 m^{-1}, which amounts to an attenuation by a factor of ten for every 6.4 m of intervening water. The coefficient at 5255A was 0.097 m^{-1}, which is equivalent to an attenuation by a factor of ten for every 24 m of water.

It should be stressed that great care was taken in these measurements to insure that the total cross section of the light beam was intercepted by the receiver at all times and, also, that only light from the projected source was measured.

Originally, a series of scattering experiments was also planned in the basin to investigate the behavior of scattered light, but the program had to be terminated before this objective was accomplished. The aureole or multipath effect for tightly collimated beams in a scattering-absorbing medium thus remains to be explored. No scattered light (multipath) contributions were detected within the precision of the present measurements.

ACKNOWLEDGMENTS

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Noncoherent beams Laser (coherent) beams Underwater attenuation Attenuation coefficient vs wavelength Relative signal vs underwater range						

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