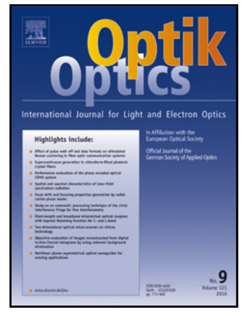

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Research on the propagation characteristics of blue-green laser through sea surface with foams

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***Abstract*:** Submarine laser communication is a kind of technology which uses blue-green laser to carry on the data transmission between the aircraft or ship and deep water. The laser transmission characteristics are greatly influenced by the air/sea interface, which becomes rougher and even covered with foams because of wind speed as well as other acting force. In this paper, by using the Kirchhoff approximation, the influences of polarization state and the incident wave on the transmission characteristics were studied, based on the Mie theory and the radiative transfer theory, the transmission characteristics of blue-green laser through rough sea surface with foams were analyzed in detail, the influences of the roughness of sea surface and wind speed on laser transmission and energy distribution were analyzed. The results show that the energy distribution of blue-green laser through sea surface is more concentrated compared to microwave, which mainly distributed in the refraction direction, the transmission characteristics have a great dependence on the roughness and wind speed. This provides a certain theoretical basis for related research.

Keywords: submarine communication; Mie theory; blue-green laser; rough sea surface; channel characteristics

1. Introduction

In recent years, the submarine blue-green laser communication has become the focus of research in the world. With the development of laser technology, its application in the military field is becoming more and more. The laser energy will occur complex process of reflection and refraction when it transmits through the sea surface, causing the laser equipment can't work properly. So, there is a great significance to understand the transmission characteristics of laser through the sea surface, and to predict the influences on laser communication.

Gordon H R [1] studied the energy transfer rate T_{wa} in the air-sea interface, Z.Jin [2] studied the influence of wind speed on sea surface reflectance, considering the coupling of atmosphere and sea surface. S. V. Salinas [3] studied the dependence of wind speed on reflection of sea surface. K.Lee [4] studied characteristics of laser diffusion from sea surface. The research mainly focuses on the backward-scattering, and the transmission problem is less involved. What's more, due to the wind speed, the surface of the sea is usually covered with foams, the size of foams range from microns to millimeters, which has significant influences on laser transmission, therefore it is necessary to study the transmission characteristics of laser through sea surface covered with foams.

In this paper, the laser transmission characteristics of the sea surface are analyzed based on the Kirchhoff Approach, Mie theory and radiative transfer theory. The distribution of scattering and transmission characteristics of the laser is obtained.

2. Laser transmission characteristics of sea surface with foams

From submarine blue-green laser communication, laser detection to laser diffuse communication, the scattering and transmission characteristics from sea surface significantly affect the performance of application system. Therefore, it is important to study the transmission characteristics through the sea surface covered with foams.

2.1. Dielectric properties of blue green laser in seawater

In the study of the interaction between electromagnetic wave and sea surface, the dielectric constant of sea water is a very important parameter. It is usually a function of wavelength (frequency), temperature and salinity. For microwave, the Dybe model is usually adopted, considering the different wavelength and water absorption characteristics, this model is no longer applicable to blue-green laser. 1995, Edward S.Fry [5] had reviewed previous research on the refractive index of seawater, an extensive summary of experimental data as well as interpolations and extrapolations was presented. Using the experimental data, an empirical equation for the refractive index of sea-water as a function of wavelength λ ($400nm < \lambda < 700nm$), temperature T ($0^\circ C < T < 30^\circ C$), salinity S ($0‰ < S < 35‰$), and pressure was obtained. Setting P=0 (i.e., atmospheric pressure)