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FEASIBILITY STUDY AND IMPLEMENTATION OF SEA RESEARCHER'S BIO-PARAMETER MONITERING BY WATER CHANNEL MODEL

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***Abstract*—Optical communication is a potential technology to realize underwater wireless communication. The experiment of underwater optical communication in the laboratory is different with that in the real water environment because the physical scale is limited. Although since recent several decades, artificial scattering agents are used to recreate underwater optical communication channels under different water quality conditions, but the similarity between experimental water and natural water is not reliable, such as the similarity in frequency domain characteristics. In this paper, several kinds of agents are evaluated to change the optical coefficients of experimental water precisely. Then, seemed as criterion for the reliability of water recreation, the frequency domain characteristic of optical communication channel in experimental water is measured and compared. The results show that the type and particle size of the agents will significantly affect its optical properties, and the frequency domain component of the optical communication signal will be affected by the agents concentration.**

Keywords—underwater optical communication; frequency domain properties; scattering agents

I. INTRODUCTION

Optical communication is a potential technology to realize long-distance high-speed underwater wireless communication. Facing the difficulty of alignment caused by uncertainty of the position of transmitter and receiver, poor mechanical stability as well as complexity of water environment, the transmission characteristics of underwater optical communication (UOC) signals under alignment conditions are difficult to obtain in the natural seawater environment. The experiments of long-distance UOC in the real marine environment are difficult, that is why there are fewer such attempts [1]. At present, the related research mainly focuses on the short-range high-speed optical communication in the laboratory.

In the laboratory, to create experimental environment of UOC which close to the real seawater, the requirement of hardware is rigorous. In order to make the experiment effective, it is necessary to ensure a long enough underwater optical channel. A common method is to use longer pools or pipes [2]. The other approach is to use sets of plane mirrors [3]. These ways are accurate and credible for simulating direct-light communication channels. To focus on the scattering of underwater light beams, different thinking are needed.

In addition to the experimental vessel, the scattering and absorption of light beams in seawater should be simulated. In UOC experiments, artificial particles of very small size, commonly known as scattering agents, are often added to water to simulate the effects of real sea water on photons. These scattering agents include: Magnesium Hydroxide ($MgOH_2$), ISO 12103-1, A4-Coarse Test Dust (ATD), and Maalox antacid. Due to the different micro-components, the optical characteristics of these agents are different.

Fig.1. Laser in water containing different amount of scattering agent.

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These artificial agents can significantly enhance the scattering characteristics of experimental water. But the composition of real seawater is extremely complex and varied. There are many organic and inorganic impurities in seawater with different colors, particle size and transparency. On the other hand, the seawater in different geographical areas is usually different. All of these lead to the unique optical properties of seawater optical channel [4]. So It is a difficult task to simulate the optical channel of sea water. Inter-symbol interference will be obvious if the seawater optical channel is long [5]. The frequency domain characteristics of underwater optical channel are also attracting attention [6-7].

II. System Description

Compared with the real seawater, the experimental water doped with artificial scattering agents is not ideal. Maalox antacid, for instance, a kind of scattering agents commonly used at present, can make the scattering coefficient of experimental water similar to that of seawater. But the albedo of water mixed with Maalox antacid is higher, which is different from that of seawater [6]. Some black dyes may be useful. In this paper, the properties of a black ink as absorbent were tested.

In terms of scattering agents, two kinds of reagents were tested, one of which is the familiar pure Aluminum Hydroxide ($AL(OH)_3$), and the other is the less common pure silicon dioxide (SiO_2). At present, new technologies in chemical industry can produce some new materials or reagents, which makes it possible for scattering agents with smaller particles and more stable sizes. In this study, the particle sizes of these two kinds of agents mentioned above are also included.

AC-S Spectral Absorption and Attenuation Sensor (Fig.2) is used to measure the relationship between the concentration of scattering agent and the absorption coefficient and scattering coefficient of water. The results describe the influence of scattering agents on the optical properties of water.

Fig.2. AC-S Spectral Absorption and Attenuation Sensor

In order to measure the influence of scattering agent on the spectrum of laser communication signal, a laser communication system consisting of a 488 nm blue-green laser emitter and a photomultiplier tube was established. Spectrum analyzer is used to measure frequency domain properties. A series of optical communication experiments have been carried out in underwater optical channels with different scattering agents.

III. Experimentl Setup

A. Scattering Agents Effect Measurement

The optical properties of $AL(OH)_3$ powder with particle size of 1 μ m, 10 μ m and SiO_2 powder with particle size of 15nm, 30nm, 50nm, 500nm as scattering agents were measured by AC-S Spectral Absorption and Attenuation Sensor.

The measurement was carried out in a 35-cm diameter, 60-cm deep stainless steel bucket. Each measurement requires 50 liters of tap water. AC-S was completely immersed in water and operated normally during the 15-minute measurement. To prevent the effects of micro bubbles on the measurement results, it's necessary to let the water stand for minutes and clean up the bubbles on the inner wall of the bucket.

A small amount of the same scattering agent is added many times to form solutions of different concentrations. The optical coefficients of each concentration solution are measured. Each addition of scattering agent powder is weighed by a precision electronic scale and recorded. It is needed to mix well before measuring. During the measurement, the ACS should be kept in normal operation for more than 15 minutes in order to ensure the stability of the data. The average values of the stable data are used as the final result.

the agent concentration of water in the experiment and the optical coefficients in the wavelength of 488 nm are measured and recorded for that the laser wavelength used in the later experiment is 488 nm.

The measurement results will be shown in the next section.

B. Frequency Domain Property Measurement

Multipath scattering and various noises are the main factors affecting the frequency domain characteristics of UOC channels. Reproduction of multipath scattering requires large cross-sectional area of experimental water, but it is difficult to achieve in the laboratory. In this article, the experimental tank is 5 meters long, 1 meter wide and 1.2 meters deep (Fig.3).

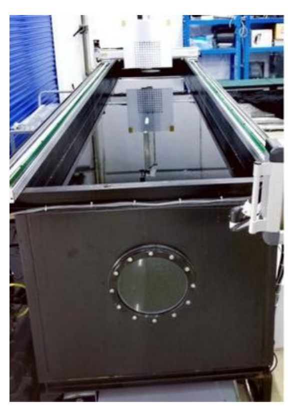

Fig.3. Experimental water tank

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The transmitter of the system includes a 488nm laser, a signal generator and an optical lens group (Fig.4(a)). Limited by the bandwidth of the laser and the performance of the signal generator, the power of the transmitting pulse signal is 1 mW, the frequency is 1 MHz, and the duty cycle is 8%.

A photomultiplier tube is used as the optical detection device at the receiving end, and a spectrum analyzer is used as the signal analysis and output device. In addition, a wide bandwidth amplifier unit is used to convert the output current of the photomultiplier into a voltage signal (Fig.4(b)).

(a) Transmitter system (b) Receiver system Fig.4.

Experimental hardware system

IV. Results

A. *Scattering Agents Effect Measurement Results*

The same source of tap water makes the initial optical coefficients of each group almost the same. To show the effect of scattering agent more intuitively, the increase of water optical coefficient caused by scattering agent is taken as the result. So the minimum values of the data in the figures are 0, which means that there is no increment of optical coefficients without adding scattering agent.

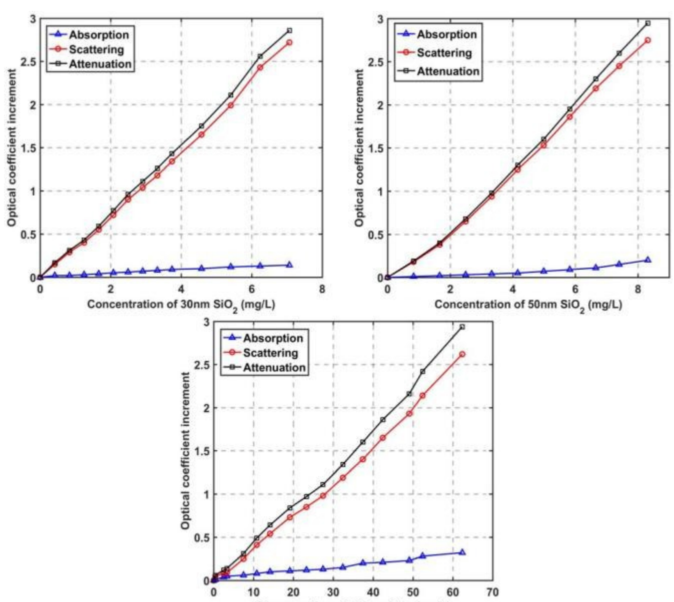

Fig.5. Effect of SiO_2 on optical coefficients of water

It can be seen in Fig.5 that the scattering agent used in the experiment can mainly increase the scattering coefficient of the water body, but has little influence on the absorption coefficient. For SiO_2, the effects of 15 nm and 30 nm particles are very similar, and they are significantly different from those of 500 nm particles.

For the same concentration of solution, the smaller the agent size, the greater the influence on the optical coefficients. This is due to the significant difference in the number of particles. This conclusion is similar to that of the $AL(OH)_3$ results.

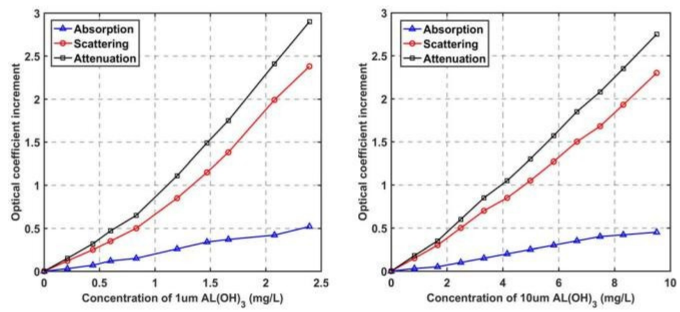

Fig.6. Effect of $AL(OH)_3$ on optical coefficients of water

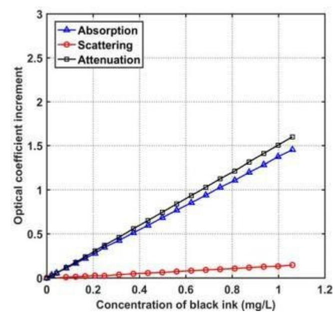

Fig.7. Effect of black ink on optical coefficients of water

For no suitable SiO_2 and $AL(OH)_3$ agents with similar particle sizes have been found, there is no direct result to compare the effects of the agent type on water. However, according to the results of each group, the influence of $AL(OH)_3$ on the optical coefficients of water is more noticeable. It can be reasonably predicted that the increase of optical coefficient increment caused by SiO_2 with the same particle size will be much lower than that of $AL(OH)_3$. The effects of black ink are expected. These data can be used to guide UOC experiments.

B. *Frequency Domain Property Measurement Results*

Scattering agent concentration, not type, has a significant effect on signal spectrum. The high frequency component of the signal is more susceptible to turbidity. The noise component in the spectrum increases with the increase of turbidity (Fig 8).

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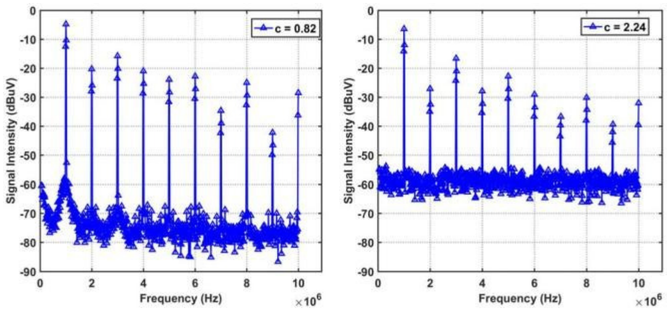

Fig.8. Spectrum of receiver signal (using 1μ m AL(OH)3 as scattering agent)

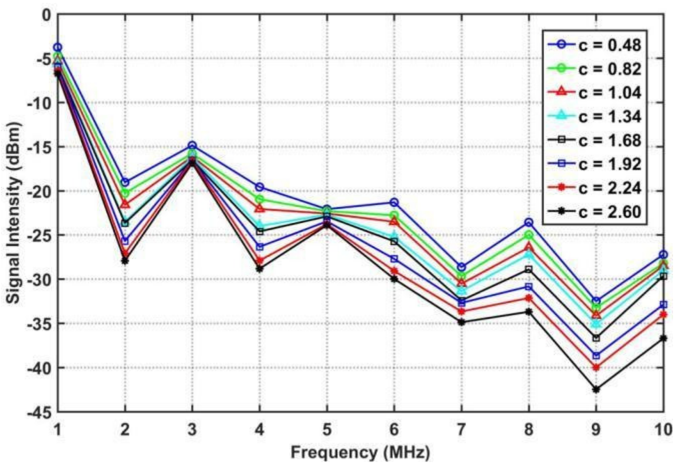

Fig.9. Trend of signal spectrums under different attenuation coefficient (Using 1μ m AL(OH)3 as scattering agent)

With the increase of frequency, the frequency domain components of signals are more sensitive to optical coefficients. The relative magnitude of frequency components also affect the sensitivity to noise caused by turbidity. This rules are applicable to different types of scattering agents with different particle sizes in this experiment.

V. CONCLUSION

The effects of two different types of artificial scattering agents with multiple particle size on the optical properties of water were measured. As a new scattering agent, pure nanoscale SiO_2 can be an alternative. The results show that the type and size of agents affect the optical parameters of water. Further work is needed to try to use different types of artificial agents to prepare water more similar to real seawater. In the experiment, the distortion of signal spectrum is more affected by the optical properties of water than by the type of agent. We plan to carry out more experiments, possibly on the effect of artificial scattering agents on beam propagation.

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