LIGHTWAVE REFLECTION AND SCATTERING ON VARIOUS MATERIALS

Takashi NINOMIYA*†, Tomoaki TODA† and Tadashi TAKANO†
***Science University of Tokyo**
1-3 Kagurazaka,Sinjukuku,Tokyo 162-8601 Japan
†Institute of Space and Astronautical Science
3-1-1 Yoshinodai,Sagamihara 229-8510 Japan

1 Introduction

The diffuse type of indoor wireless infrared communication system is considered to be one of the possible the scheme for the construction of further LAN style. In this system, scattering of light from the IR emitter on the ceiling is received on the detector. The optical properties of the ceiling are important for this system. The scattering caused by air-conditioning units and ventilator and fluorescent on the ceiling must be carefully investigated. The experimental characterization of the reflection pattern on the surface of various materials is demonstrated. Numerical evaluation of the experiment is also done.

2 Measurement setup

IR LED(λ=about 800nm) and collimation lens with the diameter of 5cm is located distant from the reflector surface by 30cm in the direction of 45° from the normal to the surface. The reflection and scattering patterns from the reflector are detected by PD. The specular component is measured along the scan path X_2 to avoid the block of the received light due to the thick pin-hole plate. The Lambertian scattering is measured along the scan path X_1. As the reflector materials, metal (aluminum), wood, plastic (acrylic) are used.

The collimated beam should have constant intensity of 0.6μw and two sharp peaks about 4.5μw at 60cm from LED, but the intensity actually changes as reported in Ref[1].In this experiment, the intensity at the distance from the collimation lens of 60cm is a half of that at 30cm. Therefore, the field distribution at 60 cm is used, as the reference to estimate the reflection and scattering loss of each materials. The distribution pattern from the IR emitter is shown in Fig.2. A linear motion is used, instead of a circular motion in order to simplify the experiment setup.

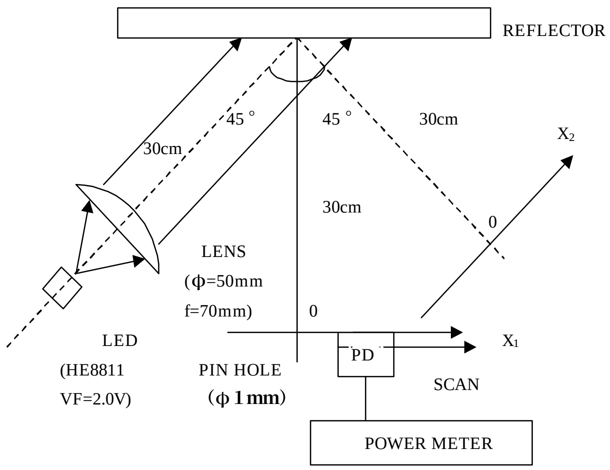

Fig.1 Measurement setup

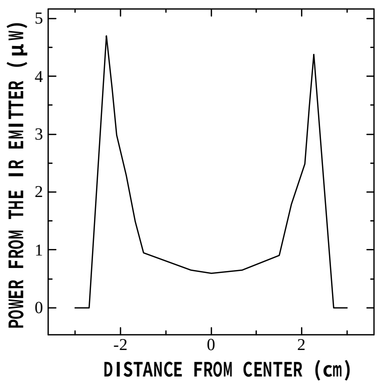

Fig.2 Power of the IR emitter at 60cm

3 Experiment results

The experiment results on each material are shown in below. The metal, plastic and wood is often used to make the indoor construction.

(a) Surface of aluminum

The measured pattern from surface of the aluminum is shown in Fig.3. This is a typical example of specular reflection. The level of the central part is 557nw.This indicates the reflectance of the materials of 0.928. Two peaks at the beam edge are upset between the left and the right of Fig 3 due to mirror reflection. The level of the right peak is 2250 nw which indicates the reflectance of 0.51.The lower value by the factor 0.51 may be due to the incomplete collimation of the scattered light at the lens edge. We take into account this difference for understanding the subsequent data.

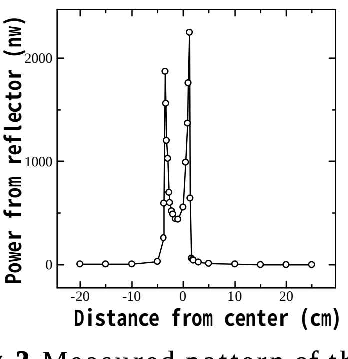

Fig.3 Measured pattern of the aluminum (X_2 direction)

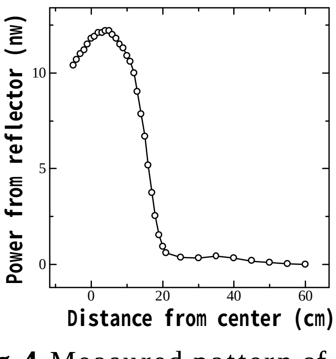

Fig.4 Measured pattern of the wood (X_1 direction)

(b) Surface of wood

The measured pattern from surface of wood is shown in Fig.4. The pattern is quite different from that in Fig.2 due to the diffused reflection. The distribution with the maximum value of 12.2 (nw) is seen as Lambertian model. On this X1 axis, the received power greatly decreases, because of blocking by the thickness of the pin-hall, as the receiving point takes farther than 10cm from the point 0 on the normal to the reflector.

(c) Surface of acrylic

The measured pattern from surface of acrylic is shown in Fig.5, and shown a mixture of the specular and diffuse reflection. The specular reflection with the reflectance of the materials of 0.07 and Lambert scattering with the maximum value of 13.6(nw) is seen. Because the material is smooth and reflective at the surface and the acrylic includes many scattering objects inside.

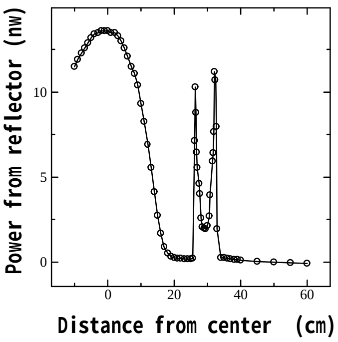

Fig.5 Measured pattern of acrylic (X_1 direction)

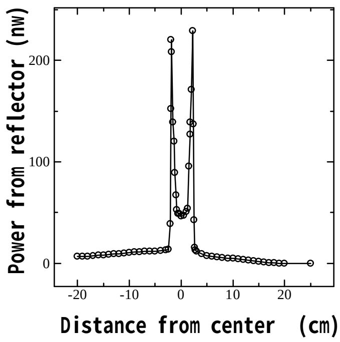

Fig.6 Measured pattern of acrylic (X_2 direction)

4 Theorotical consideration

The reflection and scattering pattern is modeled using eqn.1. [2]

Where θ_i; the incidence angle; θ_o; observation angle, ρ; surface reflection coefficient, $R_i(y)$; incident optical power at y axis, r_d; the percentage of incident signal that is reflected diffusely and assumed values between 0 and 1, m; the directivity of the specular component of the reflection, h; the distance between the reflector and X1 axis.

$$R(\theta_i, X_1) = \frac{\rho}{\pi}\int R_i(y)\{r_d\cos(\theta_o) + (1-r_d)\cos^m(\theta_o-\theta_i)\}dy \quad \text{---(1)}$$

$$\theta_o = \cos^{-1}\left(\frac{h}{\sqrt{x_1^{\,2}+h^2}}\right) \quad \text{---(2)}$$

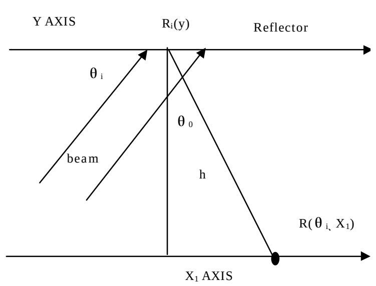

Fig.7 Reflection and scattering on the reflector

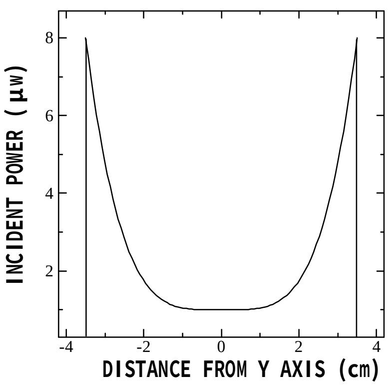

Fig.8 Incident power

The eqn.1 and 2 are calculated in the following condition : θ_i=45 h=30cm.

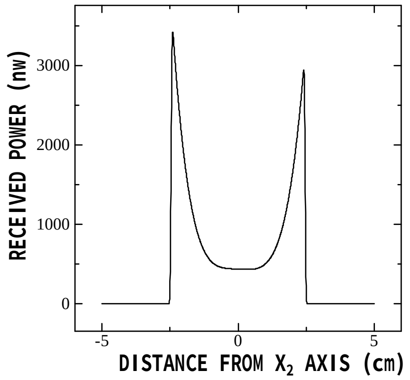

Fig.9 Specular model

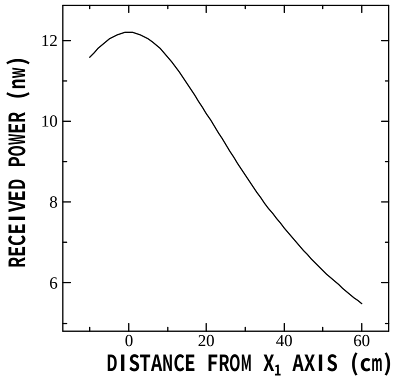

Fig.10 Diffused model

The result for r_d=0 is shown in Fig.9. Compared into Fig 3, the value at the beam edge is different. Because incomplete collimation of the scattered light at the lens edge. The result for r_d=1 is shown in Fig.10. The experimental result shown in Fig 4 corresponds to the pattern of Fig.10 is subtracted by the blocking effect of the pin-hole.

5 Conclusion

(1) Various materials are characterized for reflection and scattering. Three typical materials are aluminum, wood and acrylic which show the specular reflection, Lambertian scattering and the mixture of the both. (2) Those materials could be used for each purpose of reflector or scatterer indoor light-wave communication systems. (3) The incident beam which is composed of a uniform and peaks at the edges is convenient to investigate phenomena in two methods of a plane wave and a sharp beam simultaneously.

References

[1] Nagashima Hiroyuki, Tadashi Takano, "Measurement of optical beam pattern at free-space link system", Proc. of 1998 IEICE Spring Conf, B-1-33.

[2] C.R.Lomba, R.T.Valadas, A.M.de Oliveira Duarte, "Experimental characterization and modeling of the reflection of infrared signals on indoor surfaces ", IEE, 1998.