An optical computed tomography by means of the absorption characteristics in 1.3 μm near-infrared region

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Introduction

Several imaging techniques to extract light components in a diffused medium have been explored. To obtain the computed tomography（CT）images, time-resolved systems was employed to discriminate the photons that was propagated with straight line in scattered medium. The optical heterodyne system, and polarization modulation system are effective as its excellent sensitivity and directionality.[1-4] These methods requires of high responsibility to detect photon. In the near-infrared region at the wavelength of 1.3 μm, the photodetector that is suitable for measurement is limited such as APD with high speed response. The sensitivity of detector is sacrificed to the response time. The optical transmittance is decreased suddenly in the highly scattering medium due to the absorption of water molecule. The heterodyne system needs the response time of a detector more than 100 kHz. The Ge-PIN photodetector that is suitable for feeble light detecting in the near-infrared region is not available.

A glass optical fiber and a pin-hole with a diameter of the 100 μm yield the collimated near-infrared light through a scattering medium. Because the spatial collimator system needs no fast response time, a high sensitive Ge-PIN photodetector was employed in the CT system.

Optical spatial collimator

The experimental sets were shown in Figure 1. The He-Ne Laser and Laser Diode at the wavelength of 1.33 μm were used for the optical source in the visible and near-infrared region individually. Through the collimator constructed with a optical fiber and a pin-hole with a diameter of the 100 μm, the system extracts photons traveling along a nearly straight line in a scattering medium. The object to be measured was attached to the rotational and translation stage. The projection was measured from all azimuth angle, two-dimensional optical images were reconstructed. The Ge-PIN photodetector that is enabled to detect 1 fW was used in the near-infrared region. The photomultiplier was used in the visible region.

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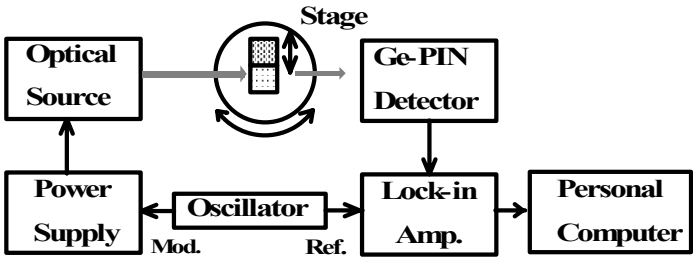
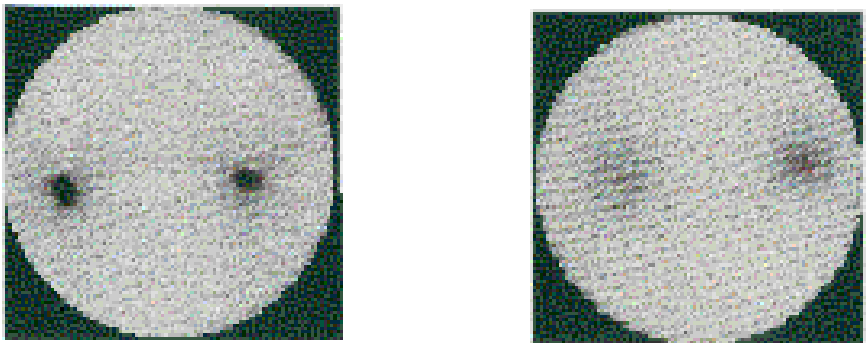


Figure 1. A schematic diagram of experimental arrangement.

Results of optical CT measurements

Effects of spatial resolution corresponding to the core diameter of optical fibre

In order to measure the Influence of the spatial resolution corresponding to the thickness of the paper, the outer frame was surrounded with the craft paper. The object was not seen clearly from the outside as same as obscure glass. The object was measured by use of the 100 μm and 200 μm diameter individually.

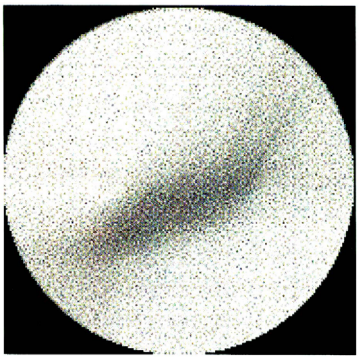


(a) 100 μm (b) 200 μm

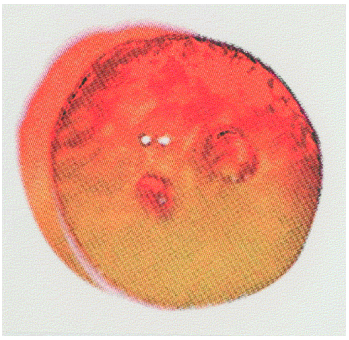
Figure 2. A comparison with a spatial resolution between 100 μm and 200 μm diameter of optical fibre. (a) 100 μm diameter (b) 200 μm diameter

The system with optical fibre of 100 μm diameter measured the diameter of the metal bar as 2.2 mm. The small diameter of the optical fibre allows high optical spatial resolution.

Measurement of permeability materials at visible area



(a) CT image



(b) Photograph

Figure 3. Optical CT image of a grape. (a) CT image. (b) Photograph

For comparison with the conventional CT method, the image of a grape with skin was reconstructed. The places of the grape seed were found without cutting. The good experimental results as comparison with the conventional OCT image method were obtained.

Measurement by means of differential absorption characteristics of near infrared

The absorption characteristics of water and oil were shown in Fig. 4.

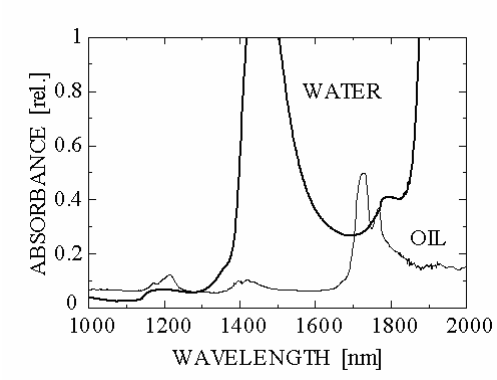


Figure 4. Characteristics of absorbance of water and salad oil in near-infrared region.

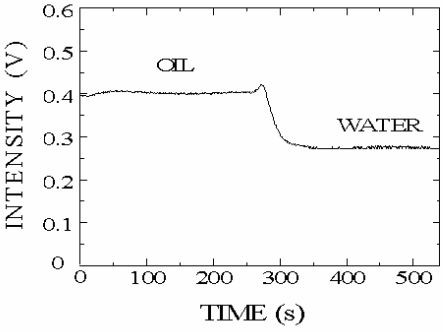


Figure. 5. Optical transmittance of water and salad oil at 1.33 μm region

Water has the absorption in the region from 1.3 to 1.6 μm. Salad oil has the absorption characteristics at the wavelength of 1.75 μm. The Optical transmittance of water and salad oil by

means of 1.33 μm Laser Diode was shown in Fig. 5.1. The cylindrical hole that was made at the center of the semi-transparent gelatin was filled with the oil. The CT image of 1.33 μm LD was shown in Fig. 6. The hole that was filled with oil of the phantom image was not recognized irradiated by a He-Ne Laser, but the 1.33 μm LD allowed to recognize the hole.

(a) CT image (b) A structure of oil phantom

Figure 6. An optical CT image at near-infrared region.

Conclusions

By means of the optical spatial collimator units were assembled with the laser diode and the glass optical fiber with a diameter 100 μm and a pin-hole with a diameter of the 100 μm. When the image construction of a grape was performed using projection data, the places of a grape seed were recognized without cutting. The image construction of grape seeds was reconstructed as same as by the conventional OCT.

The preliminary CT measurement in the near-infrared region at the wavelength of 1.3 μm was achieved by use of the absorption characteristics. By means of the difference in characteristics of near-infrared absorption, the image of a cylindrical oil phantom in gelatin was reproduced. The application to the measurements of protein and lipid in the wavelength range of 1 to 2 μm will be expectable.

References

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