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Safe and accurate diagnosis without blood removal

Commercialization of Cardiovascular OCT

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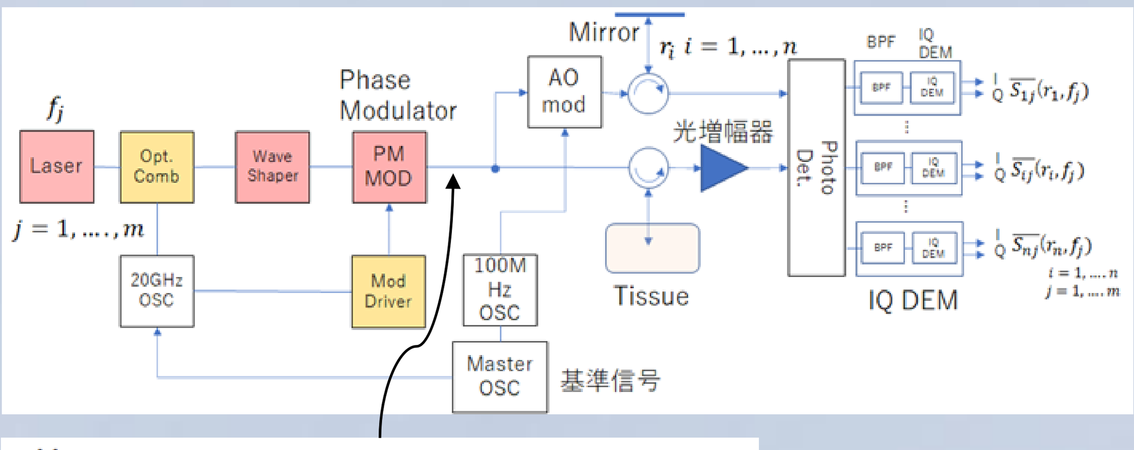
ABSTRACT

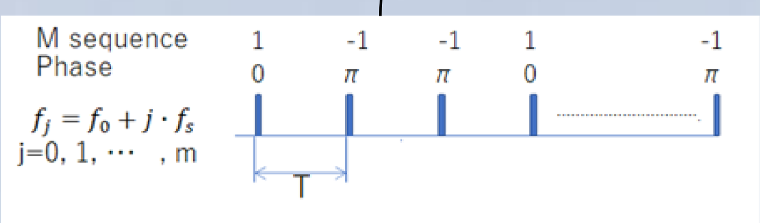
The one-dimensional image information to be obtained by OCT can be approximated by the finite discrete frequency spectrum, that is, the image information can be obtained by measuring the phase and amplitude of the reflected wave at each discrete frequency. As a result of simulating a new OCT incorporating spread-spectrum communication technology, which is well known in the communication field as a high-sensitivity measurement method, It was confirmed that the new method is effective in improving sensitivity and suppressing background noise generated due to light scattering in the living body.
A Bessel beam is used to further improve depth, resolution, and sharpness. Compared to the Gaussian beam, the Bessel beam can generate a longer beam with a small diameter, reduce the effective attenuation of the beam, have a self-regeneration function, and also have a scattering noise suppression function, so the depth of penetration long observation is possible. The superiority of the Bessel beam is clarified in the paper. [2]
Concluding, by combining the new OCT and Bessel beam, it is possible to provide a cardiovascular OCT that can observe the perivascular membrane without removing blood. Since this combination has a high depth of invasion and high resolution, it can be expected to contribute to many medical fields such as cancer diagnosis and ophthalmic diagnosis.

METHODS

A coherent carrier is used to generate a two-phase phase-modulated picosecond pulse of M-series code, branching, irradiating the tissue with one to obtain a reflected signal, frequency-converting the other, and illuminating the mirror. The reflected wave is generated as a reference wave. If the optical path difference between the reflected signal and the reference wave is within the pulse width, two-wave interference occurs. The two-wave interference signal is detected, and the IQ signal of this interference signal is extracted to obtain the discrete spectrum. This is the frequency spectrum of the one-dimensional image signal. A spectrum can be similarly obtained at a plurality of optical frequencies having a frequency difference that is an integral multiple of the base frequency determined by the pulse width. One-dimensional image information can be obtained by synthesizing these spectra. By changing the optical path length of the reference wave, it is possible to obtain a one-dimensional entire image of the target range.
The block diagram of the system is shown below.

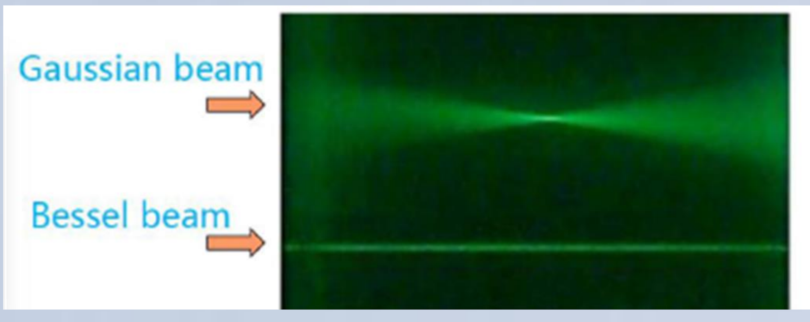
Fig.1 Block diagram of New OCT (M-FD-OCT)



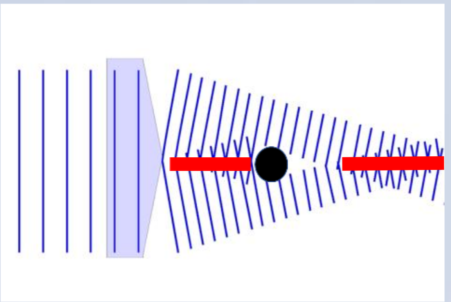


M-sequence DPSK modulated Pulse

We use a Bessel beam instead of the traditional Gaussian beam to irradiate the Tissue. For cardiovascular OCT, we will develop and use a very small Bessel beam generator with a diameter of 1 mm or less at the tip of the catheter.
The Bessel beam has features such as being able to maintain a narrow beam over a long distance, being able to regenerate the beam behind an obstacle on the beam and suppressing effective loss.



a narrow beam over a long distance



regenerate the beam

Fig.2 Comparison of Gaussian beam and Bessel beam

RESULTS

New method OCT (M-FD-OCT)
Sensitivity: 150dB-200dB (current SS-OCT: 100dB)
Dynamic range: 150dB-200dB (current SS-OCT: 60dB)
The observable depth is determined by the dynamic range.
New method OCT depth> 3 X SS-OCT depth
Bessel beam
Significant reduction of beam attenuation in blood: ≈ 8dB/mm or Less

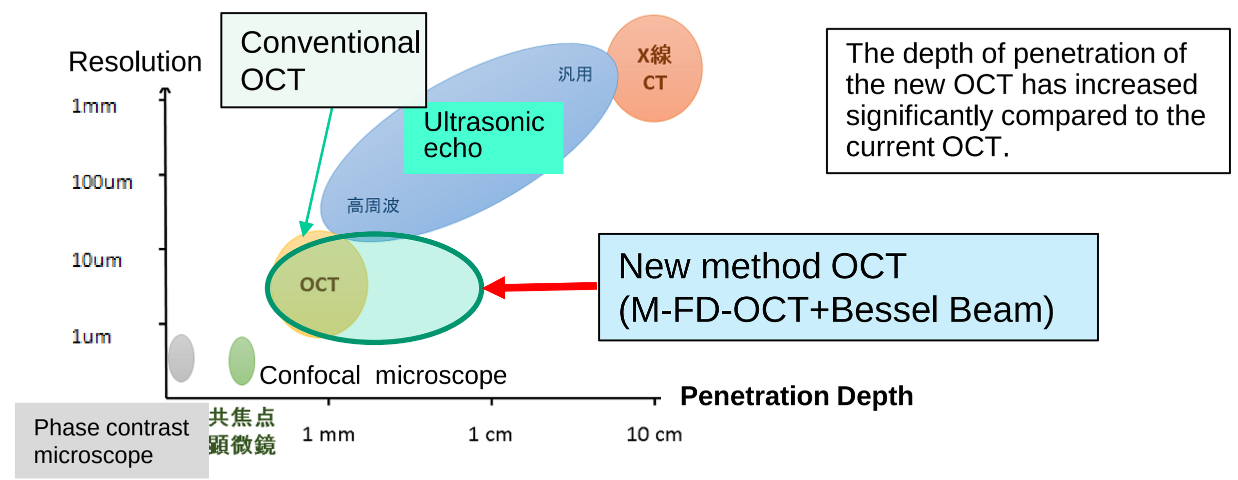
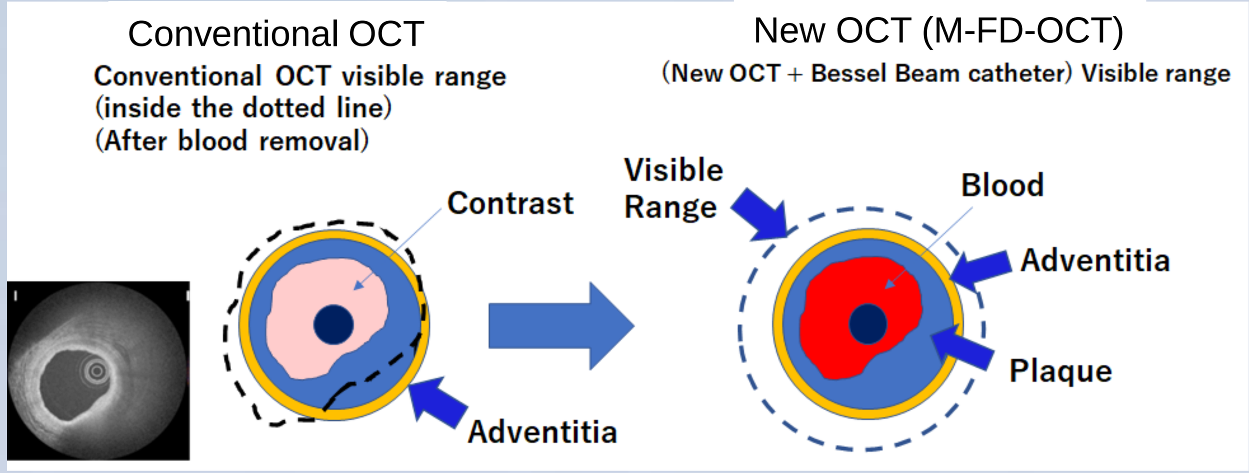


Table 1. New Cardiovascular OCT vs. Conventional OCT/IVUS

	New OCT	Conventional OCT	Conventional IVUS
Need for Blood Removal	No	Required	No
Ability to observe Adventitia	Yes	Difficult	Yes
Resolution	10um	10um	100um
Observation of Vulnerable Plaque Diagnosis	Yes	Yes	Difficult
Discrimination of Plaque Composition	Yes	Yes	Difficult
Determining Stent Size and Position	Accurate	Difficult	Somewhat inaccurate

Risks associated with blood removal

- As the amount of contrast medium used increases, the risk of worsening renal failure, myocardial ischemia, arrhythmia, and thrombus increases.
 (Risk to patients)
- Difficult to remove blood by flushing at the entrance of coronary arteries, chronic complete occlusion lesions, etc.



CONCLUSIONS

The newly proposed OCT (M-FD-OCT) uses a pulse train signal phase-modulated with pseudo-noise that has autocorrelation, and can greatly improve the signal-to-noise ratio due to the range gate function and correlation gain. Furthermore, by using an optical amplifier, a high-sensitivity OCT that can capture reflected signals below the very weak shot noise is realized. Further, the signal-to-noise ratio can be improved optically by using the Bessel beam. Therefore, it was found that an image with a depth of 4-6 times that of the conventional OCT (SS-OCT + Gaussian beam) can be observed. The new OCT provides a cardiovascular OCT that does not require blood removal and can observe the epivascular membrane. Since no blood removal is required, there is less risk for the patient and the equipment is easier to handle. In addition, since the resolution is higher than that of IVUS, which is currently the mainstream, highly accurate diagnosis and treatment are possible.
Since the new OCT has a high degree of invasion and high resolution, it enables non-invasive diagnosis in many medical fields such as diagnosis of cancer progression and ophthalmology. Even during tumor resection surgery, the resected part can be monitored and accurate and safe surgery can be performed. Furthermore, it is possible to replace one part in the field of X-ray diagnosis, and there is a possibility that the risk of exposure can be eliminated.

REFERENCES

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