

What is the Futuristic Type of OCT ?

A photograph of the Wakayama Medical University building, a large multi-story structure with a central tower and several wings, situated behind a body of water. The building is modern with a mix of brown and white facades. In the foreground, there's a blue body of water and a bridge. The background shows a green hill under a clear blue sky.

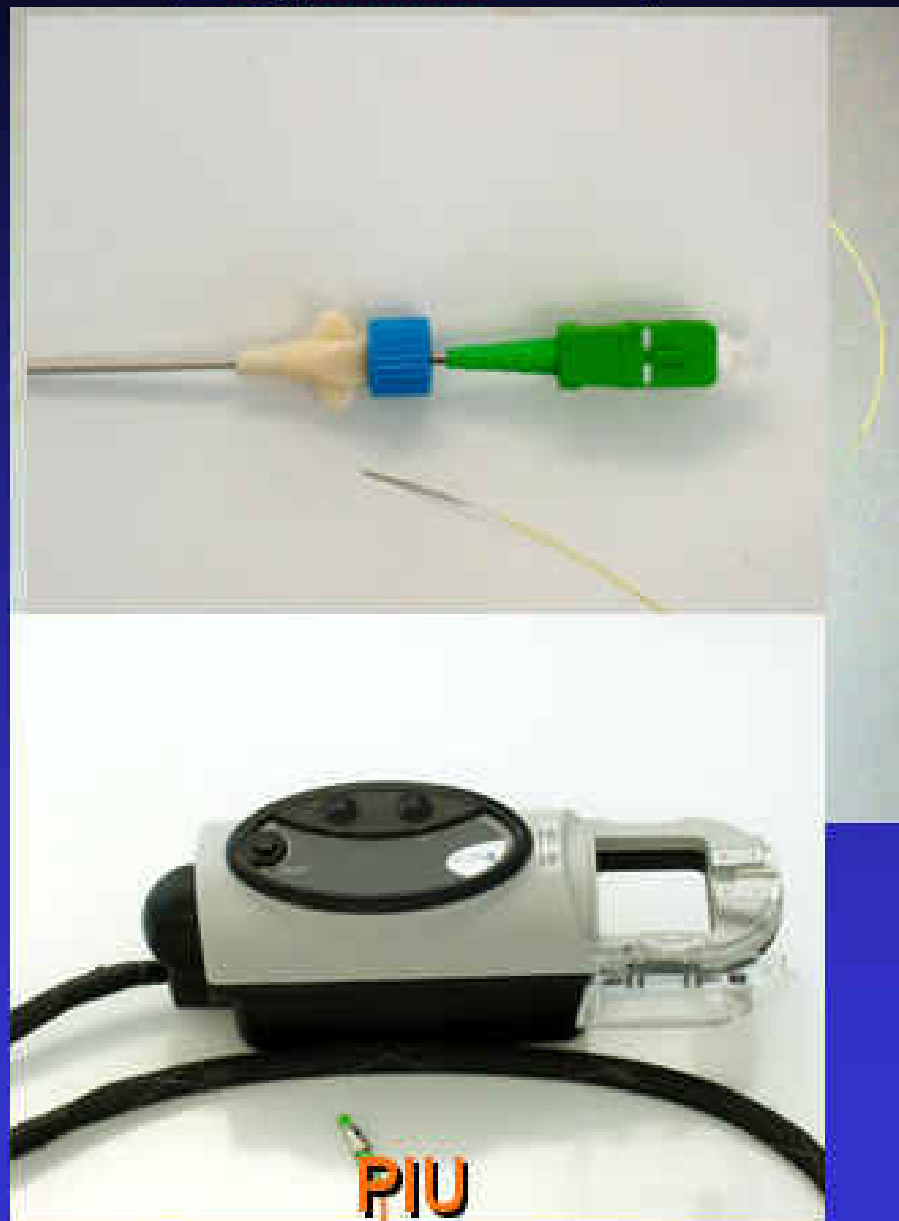
Takashi Akasaka, M.D.
Department of Cardiology
Wakayama Medical University



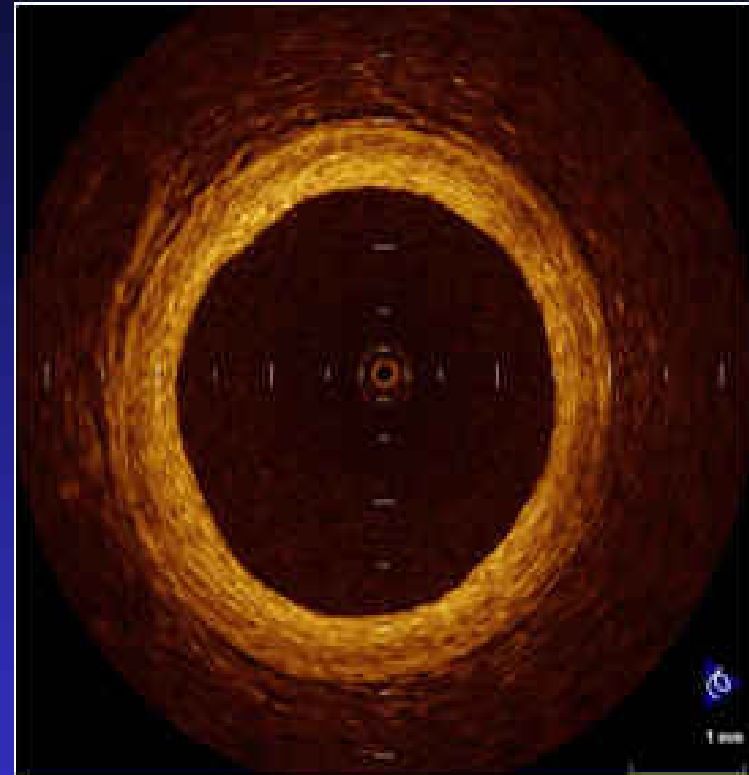
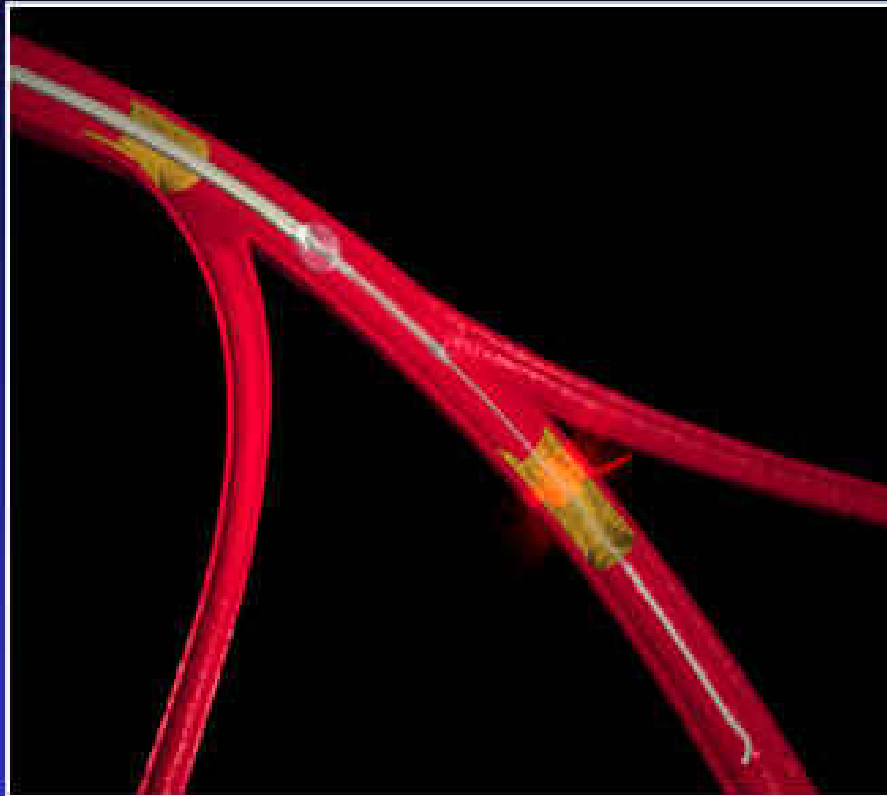
The 3rd Imaging & Physiology Summit 2009

Wakayama Medical University

OCT system (M2 or M3, LightLab Co.)



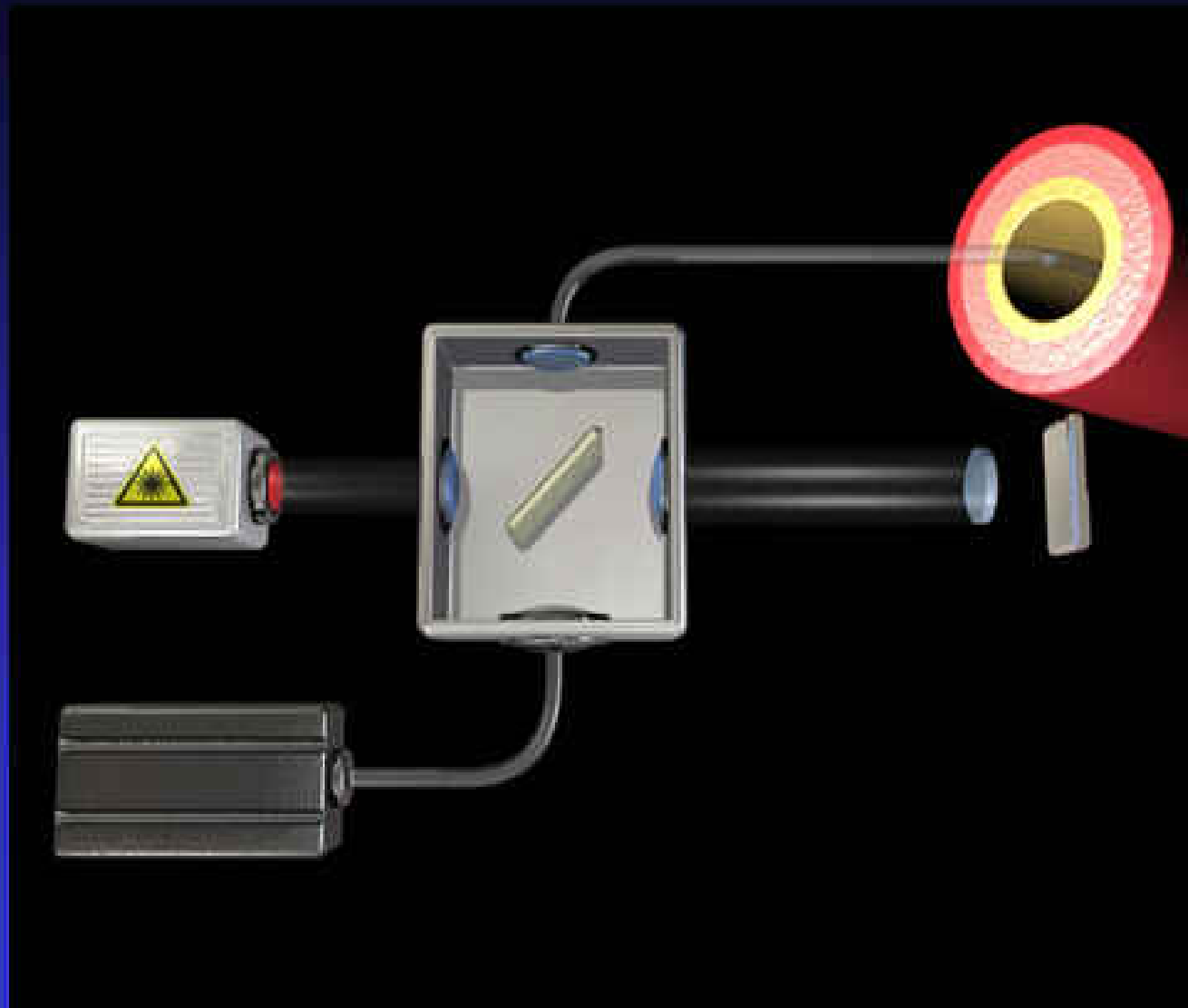
Optical Coherence Tomography (TD-OCT)



- Size of imaging core (0.4 mm)
- Microscopic resolution (10-20 μm)
- Real time Imaging (15 frames/s)



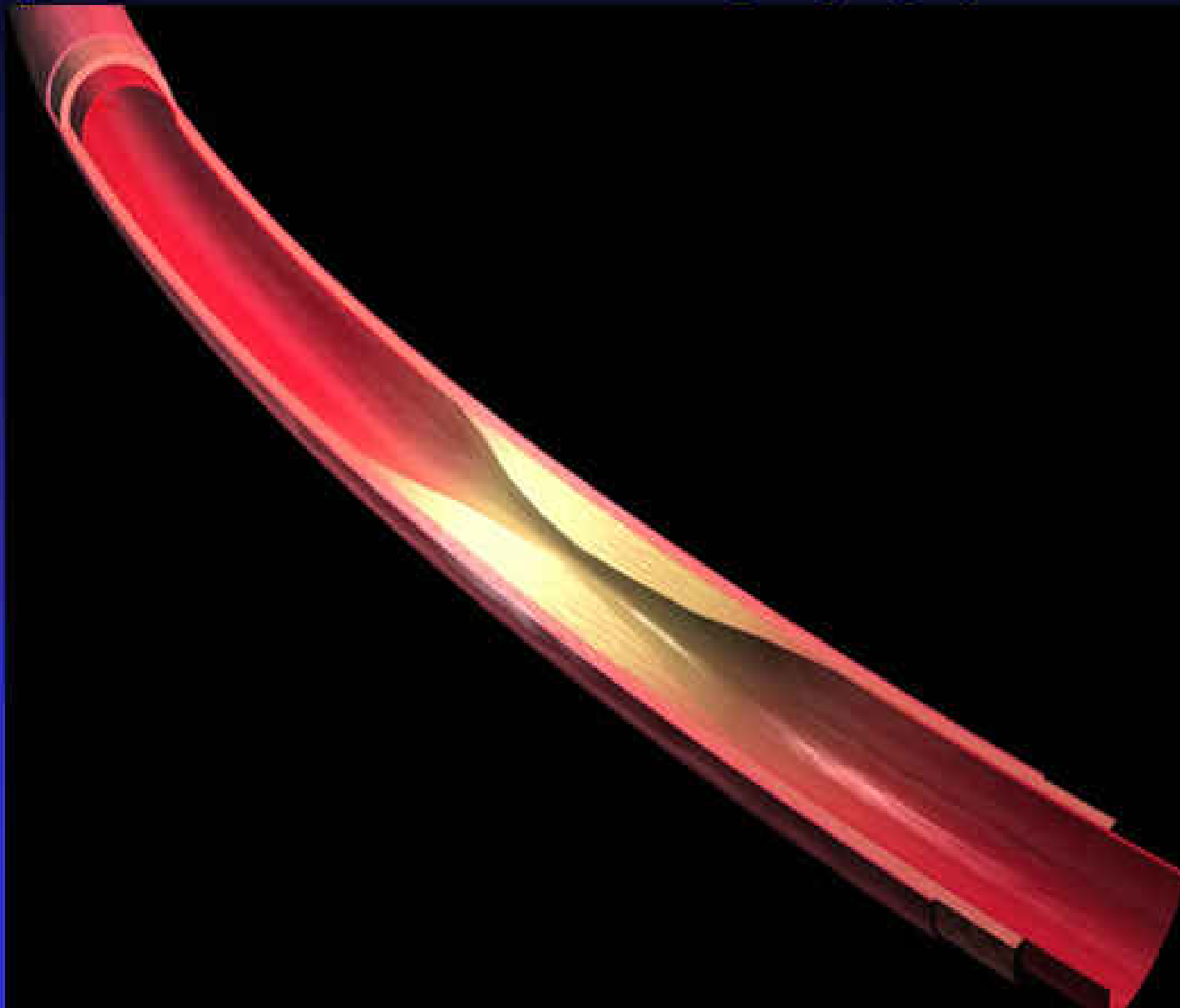
Time-Domain OCT



Separate an infrared light beam into 2 directions (a target & a reference).
Move reference mirror to make coherence.



Optical Coherence Tomography (TD-OCT)



Limitations of the present TD-OCT system (M2/M3)

Limited length of image acquisition (maximum 3 cm) because of limited occlusion time to avoid myocardial ischemia.

Difficult to obtain images of LM, and the proximal site of LAD and LCX, and RCA ostial portion because of balloon occlusion and flushing system.

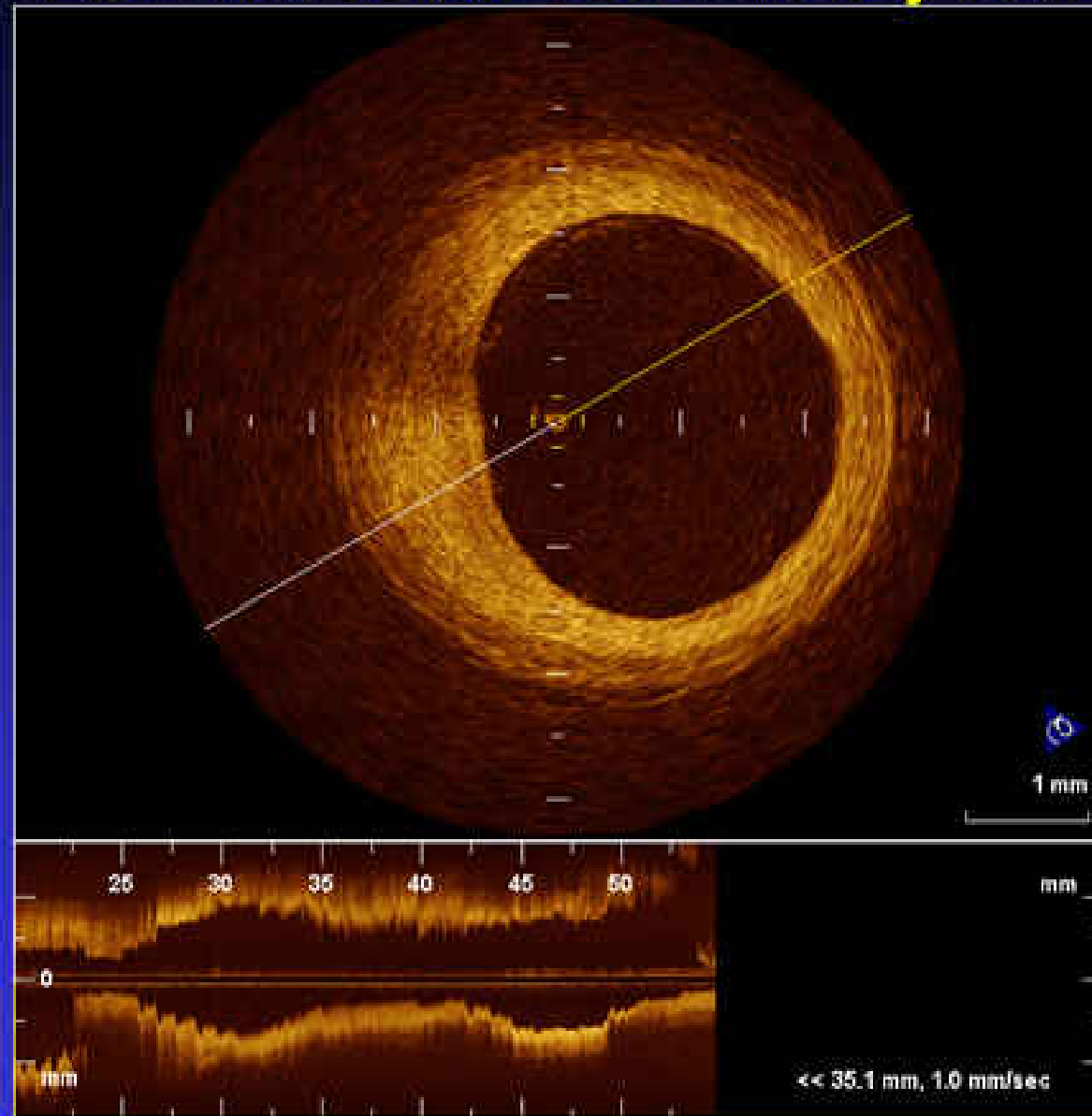
Limited depth of images because of the very shallow penetration depth of infrared light beam (about 1.5mm).

Image distortion because of limited frame rate (15/sec).

Poor images at the opposite site if the image catheter is displaced to one site because of poor beam number (240) in one sectional image.



10% low molecular dextrose 3ml/s by auto injection

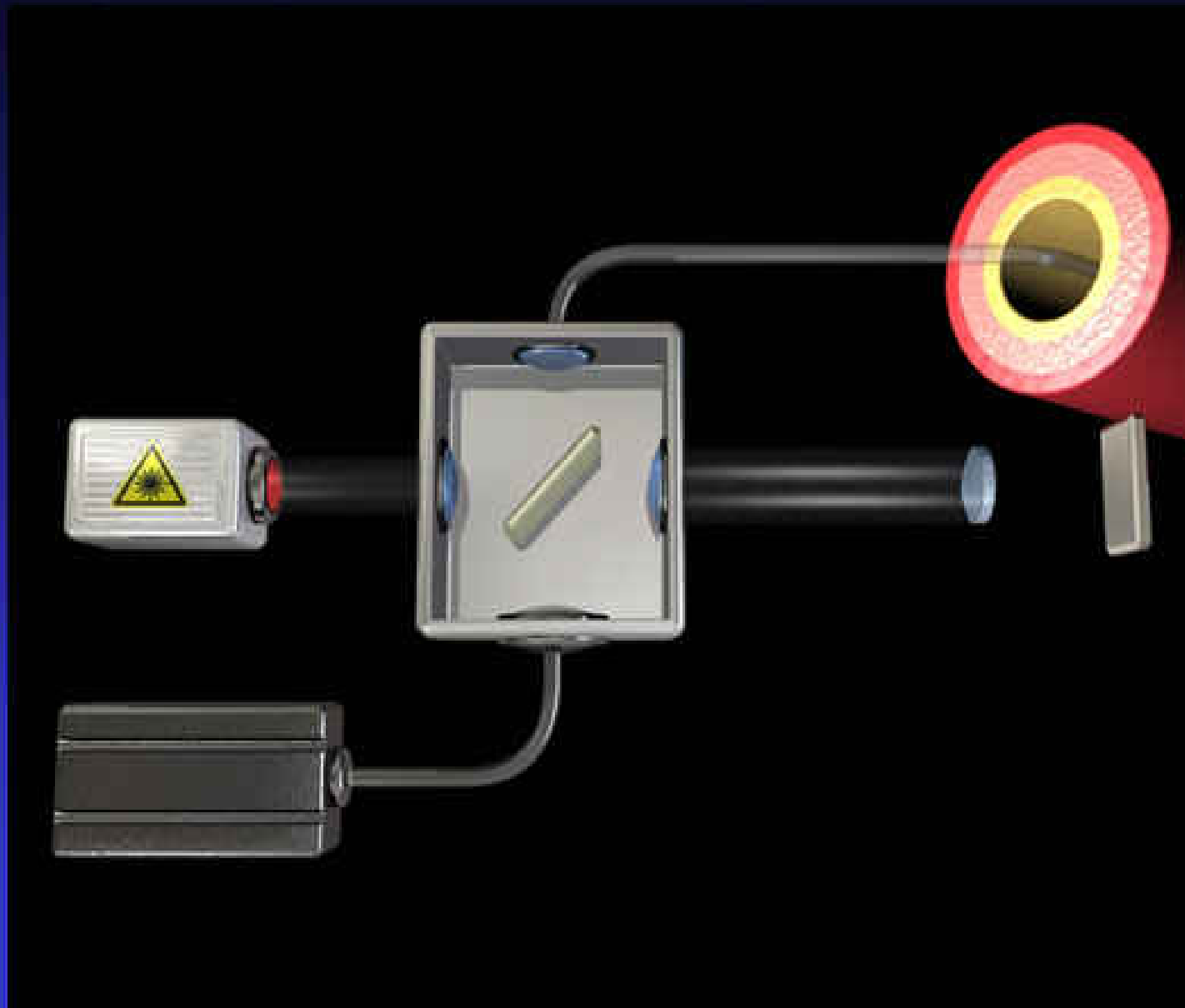


Kataiwa H, et al. Circ J 72:1536-1537, 2008

Wakayama Medical University



Frequency Domain OCT (FD-OCT/OFDI)



Frequency-domain OCT (OFDI)

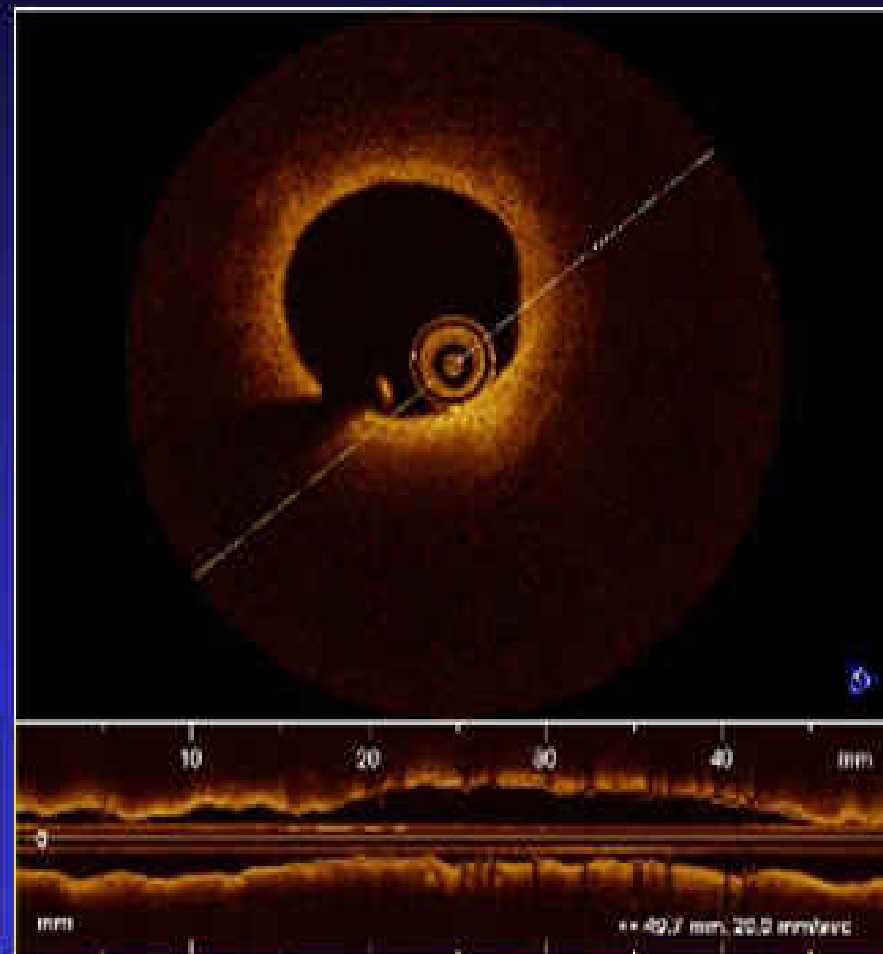
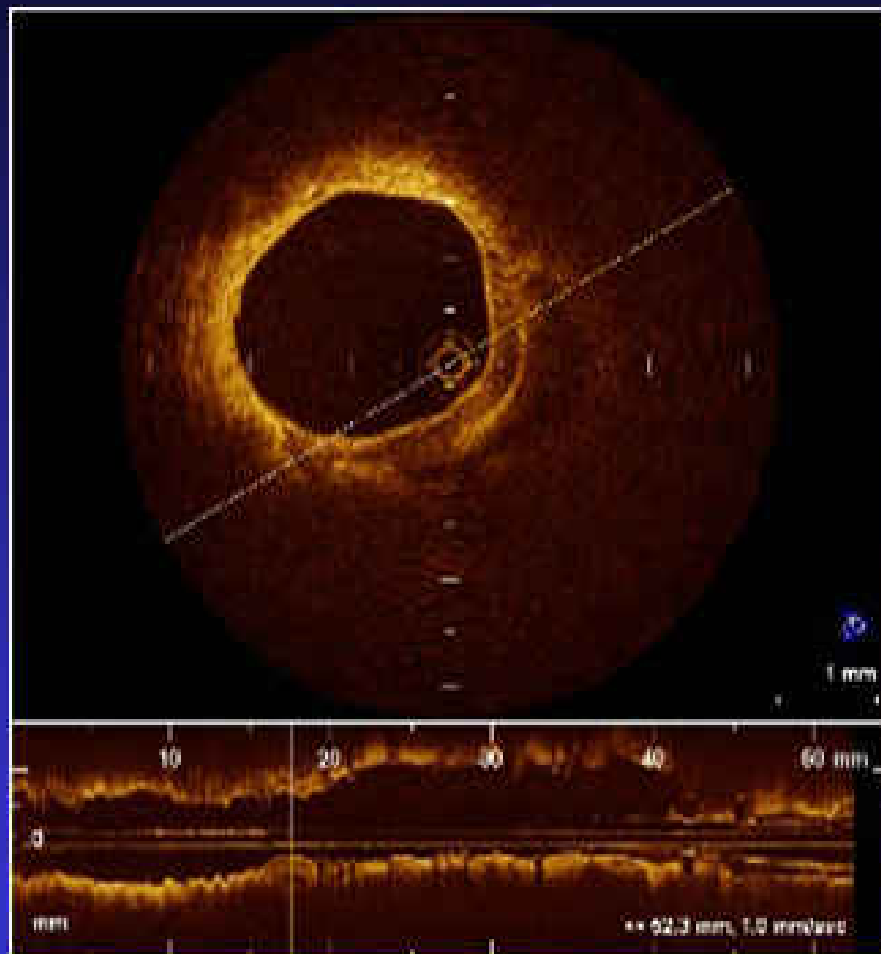


Time-domain OCT vs Frequency-domain OCT

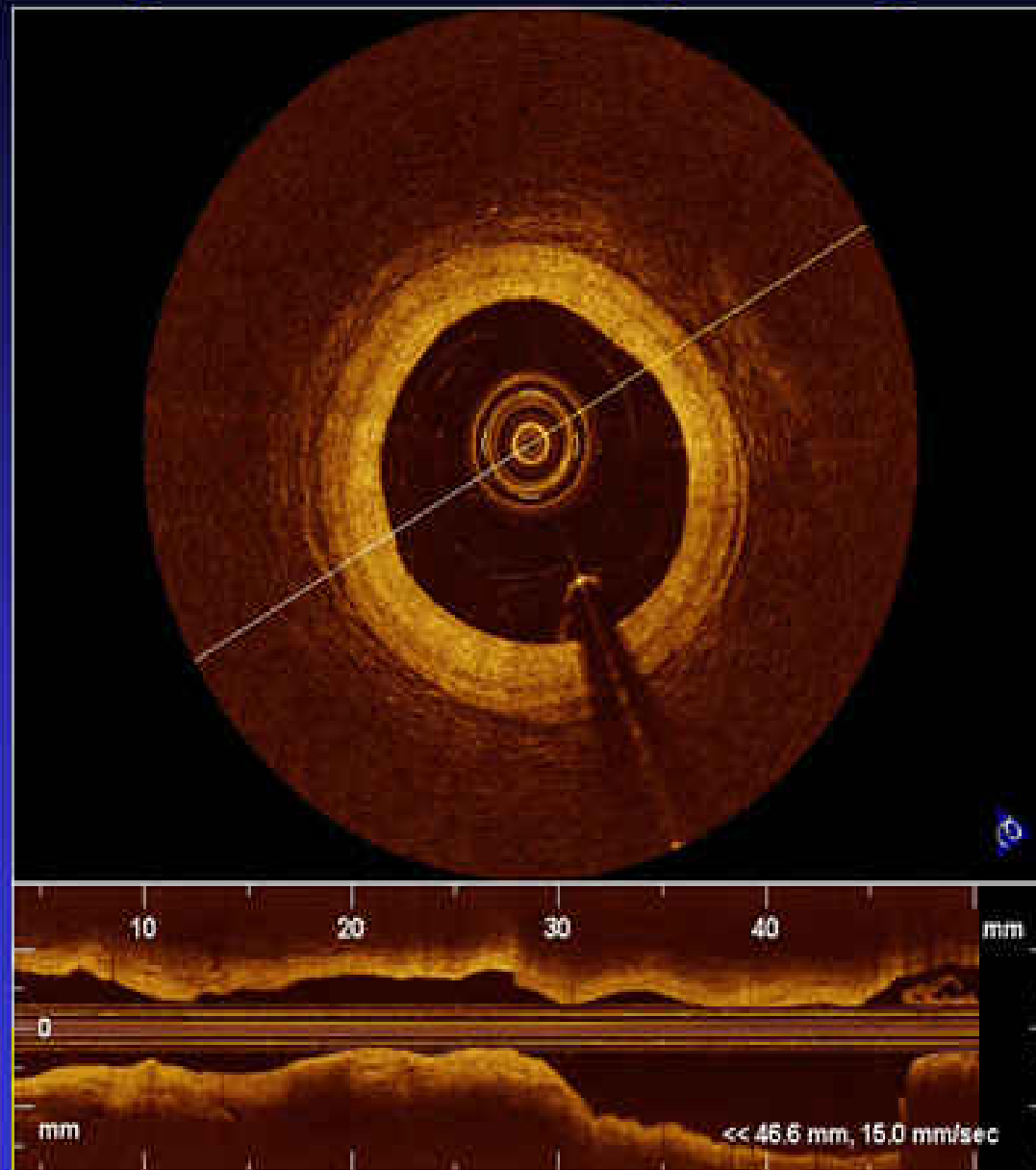
	<i>Time-domain OCT (M3 system)</i>	<i>FD-OCT (C7 system)</i>
<i>Max. Frame Rate</i>	<i>20 fps</i>	<i>100 fps</i>
<i>Max. Pullback Speed</i>	<i>1.5 mm/s</i>	<i>20 mm/s</i>
<i># Lines / frame</i>	<i>240</i>	<i>450</i>
<i>Scan diameter (in saline)</i>	<i>6.8 mm</i>	<i>8.2 mm</i>
<i>Lateral Resolution</i>		
<i>@ Z = 3 mm</i>	<i>30 μm</i>	<i>30 μm</i>
<i>@ Z = 1 mm</i>	<i>94 μm</i>	<i>40 μm</i>
<i>Axial Resolution</i>	<i>15 μm</i>	<i>15 μm</i>



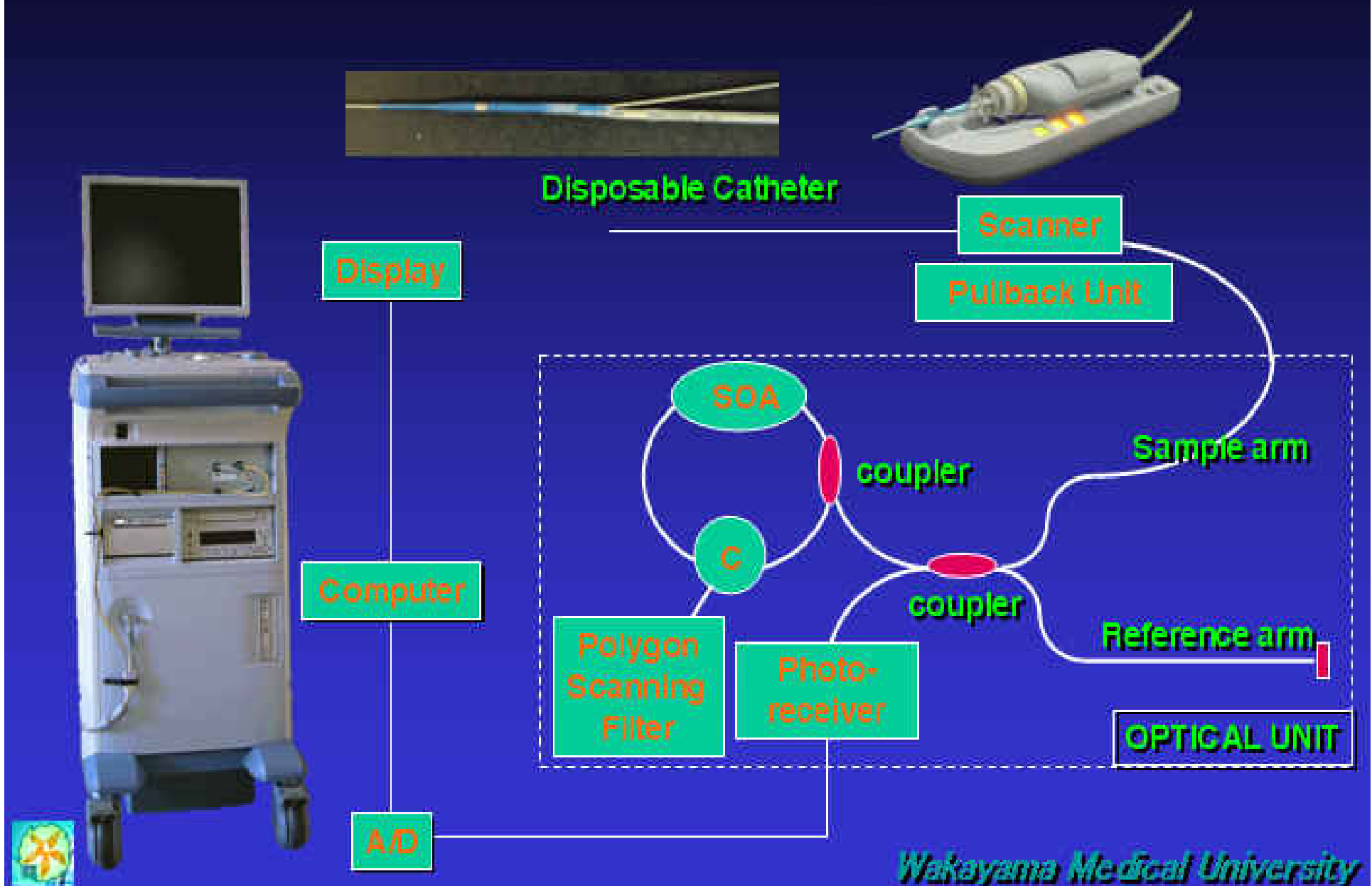
Time-domain OCT vs. Fourier-domain OCT



Frequency domain OCT (C7, Lightlab Co.)



Terumo OFDI (Optical Frequency Domain Imaging) System

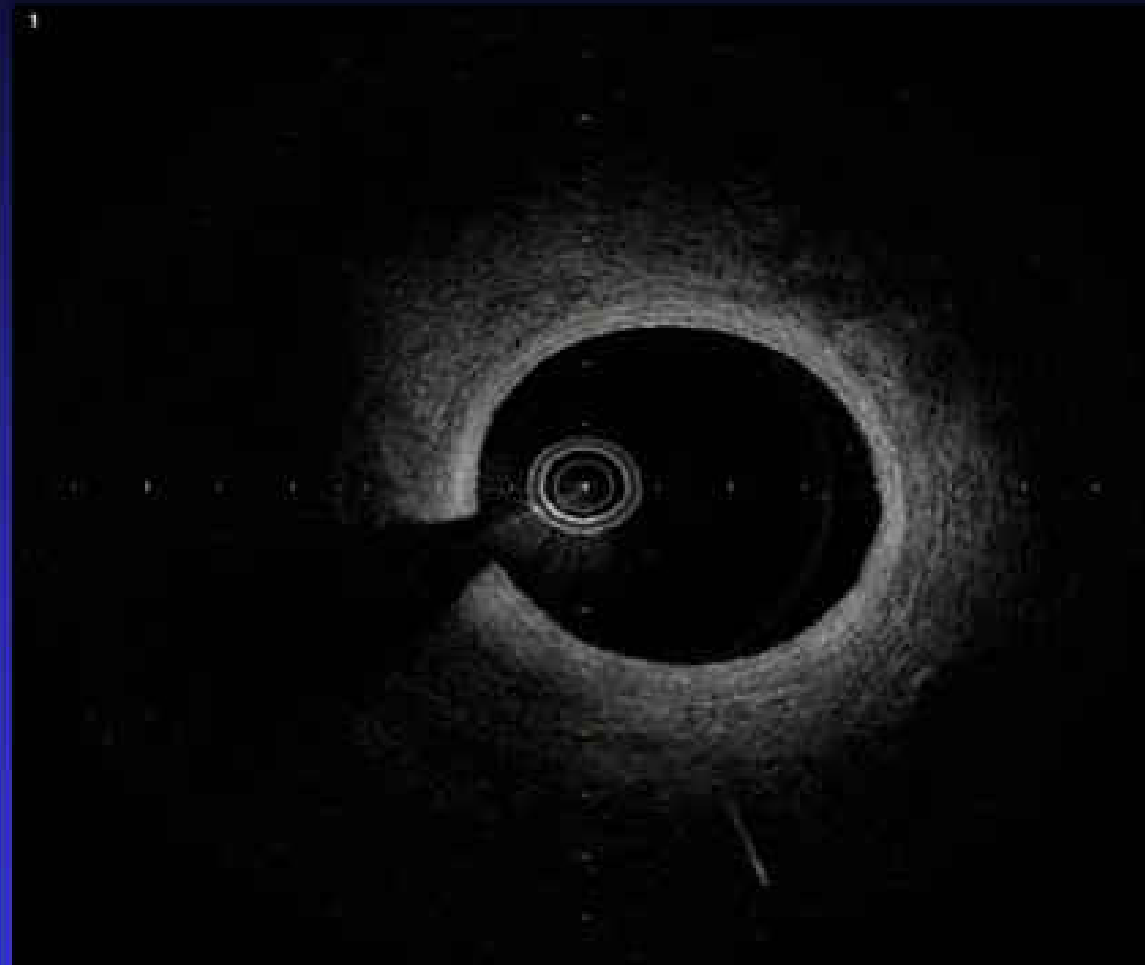


Terumo OFDI (Optical Frequency Domain Imaging) System

Frame Rate	<u>30 fps – 160 fps</u>
Pullback Speed	<u>0.5 mm/sec – 40 mm/sec</u>
# Lines/frame	<u>512</u>
Scan diameter (in saline)	10 mm
Lateral Resolution @ Z = 2.5 mm	30 μ m
Axial Resolution	20 μ m
Imaging Window Profile (Catheter)	2.4 Fr <u>(0.80 mm)</u>



Terumo OCT (OFDI)



Advantage of FD-OCT compared with time-domain OCT

Feasibility of FD-OCT imaging was examined in 20 stented segments (diameter: 3.0 ± 0.4 mm; length: 18 ± 4 mm) compared to TD-OCT.

	TD-OCT	FD-OCT	p-value
Procedure success, %	100	100	NS
Time for image acquisition, sec	27 ± 9	3 ± 1	<0.01
Length of imaged segment, mm	26 ± 18	48 ± 1	<0.01
Sew-up artifact, %	17	3	<0.01
Analyzable frame, %	81	99	<0.01

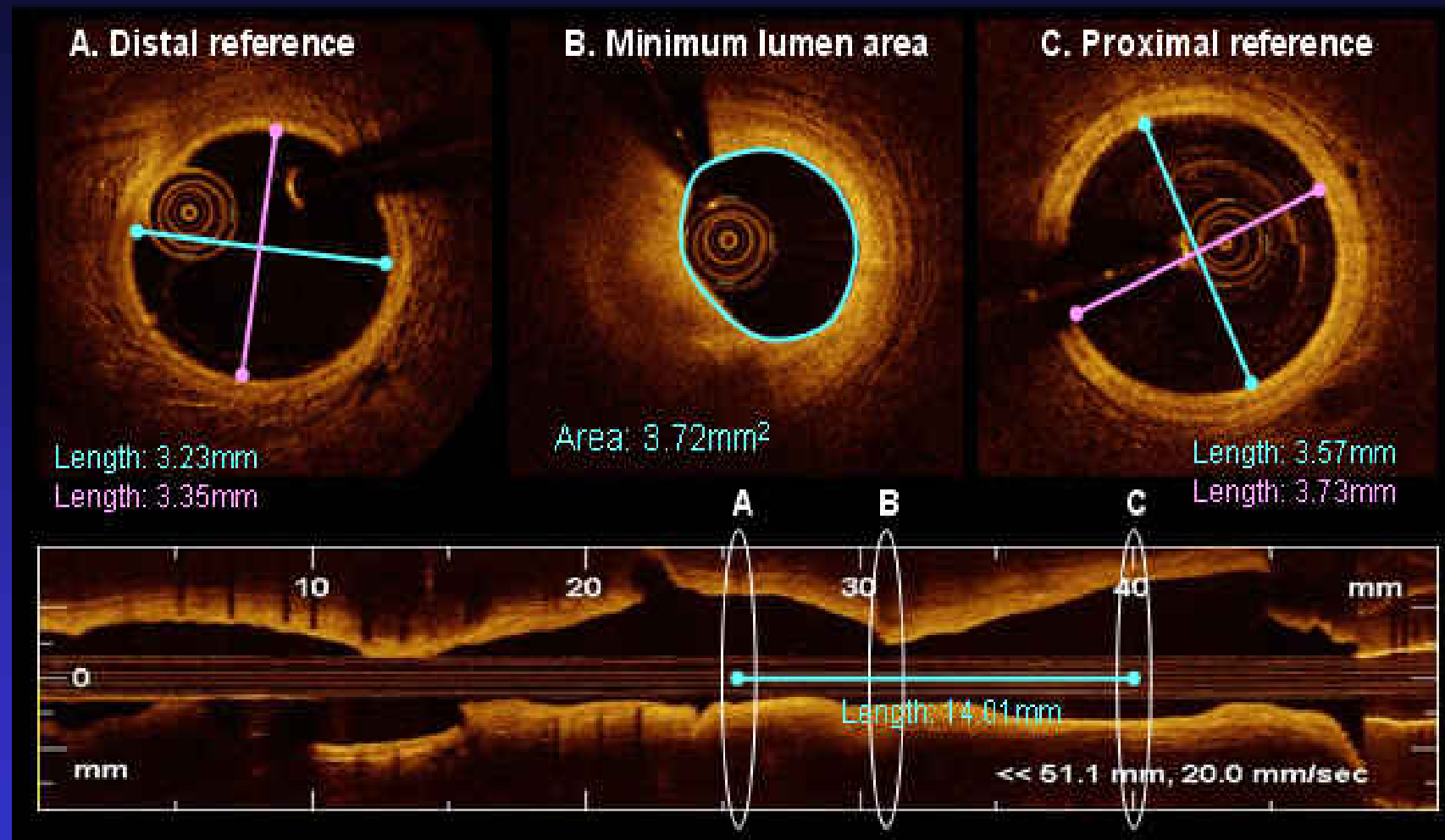
Conclusion: FD-OCT has better performance in the clinical setting and the potential to overcome several limitations of conventional TD-OCT systems.

Takarada S et al, Catheter Cardiovasc Interv. 2009 in press

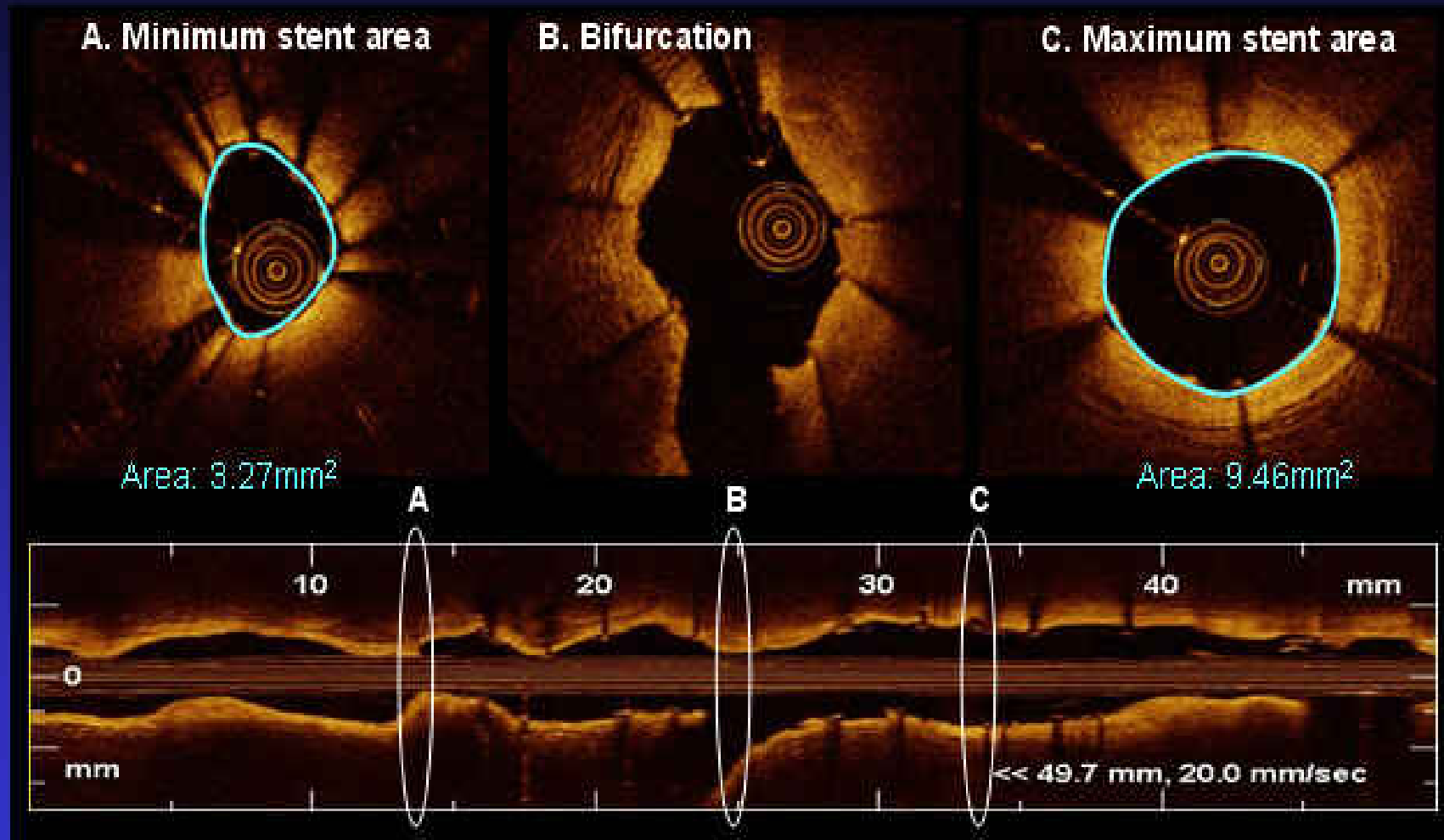


Wakayama Medical University

FD-OCT measurements at pre-intervention



FD-OCT measurements at post-stenting



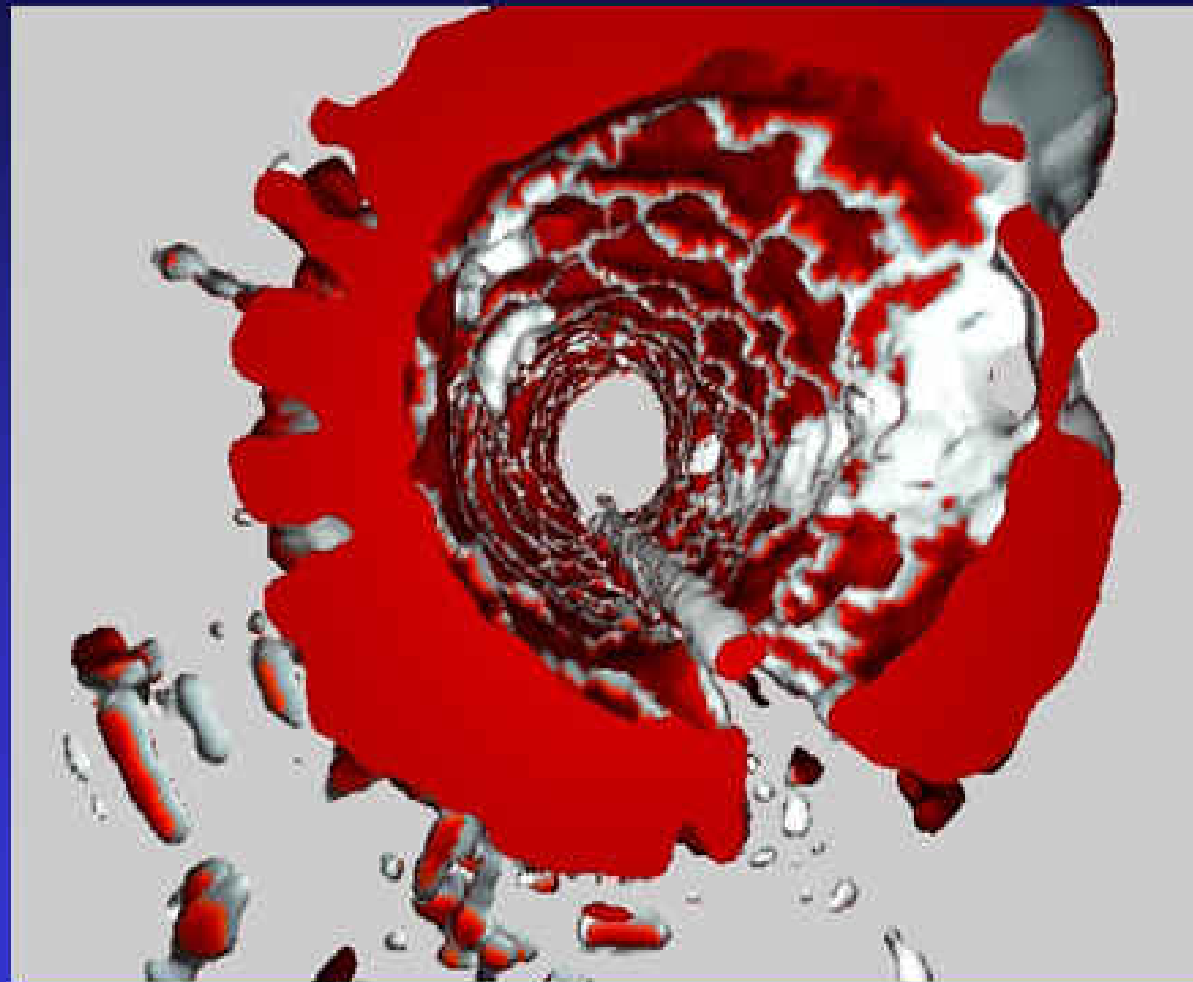
Inconsistent stent strut distribution



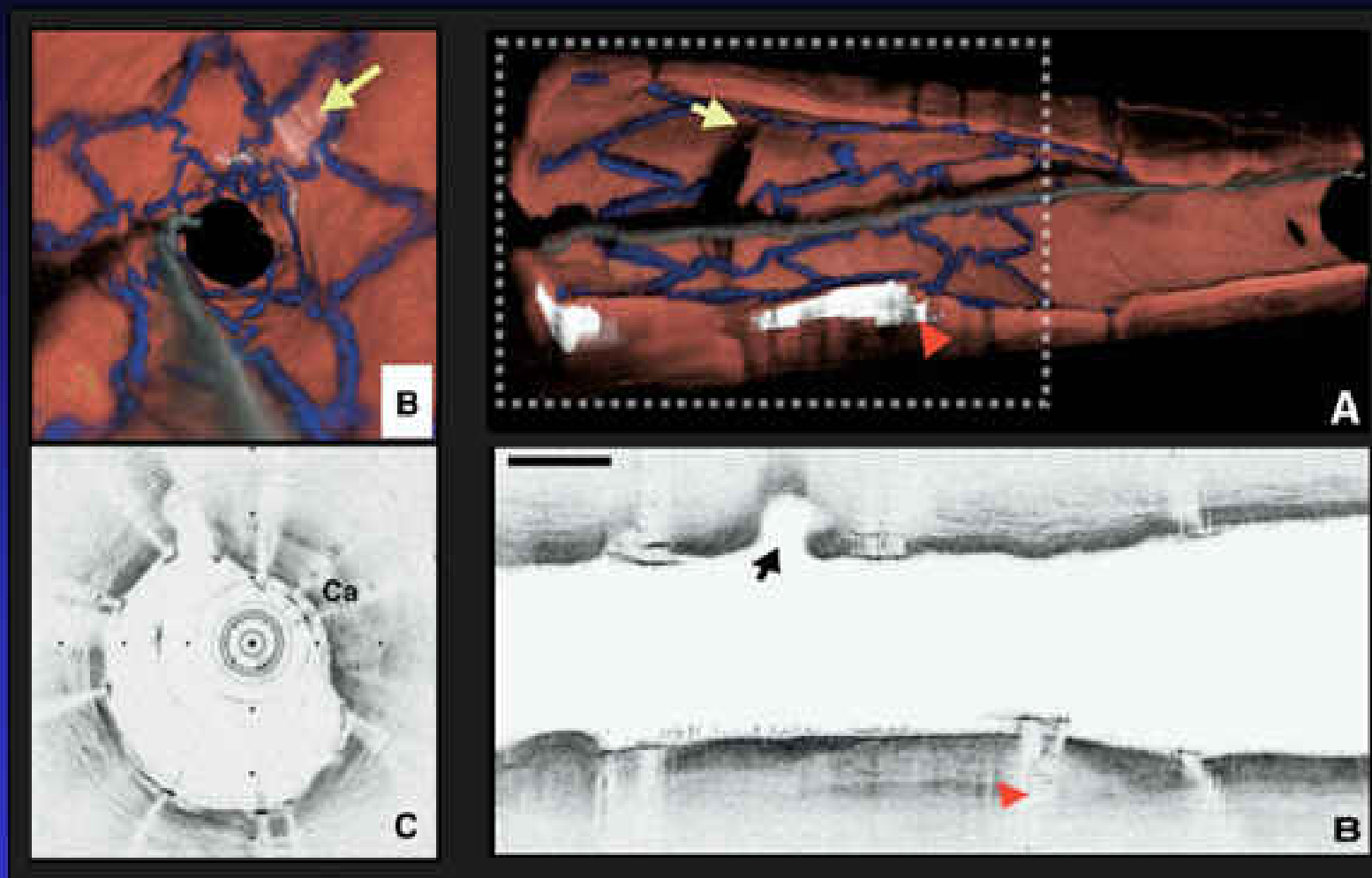
Be careful to diagnose inconsistent stent strut distribution because image section cannot always be guaranteed as perpendicular to the vessel axis.



3-D OCT image analysis and the diagnosis of inconsistent stent strut distribution



3D FD-OCT imaging



When this technology is fully exploited, OCT may be a powerful clinical tool for guiding coronary intervention.

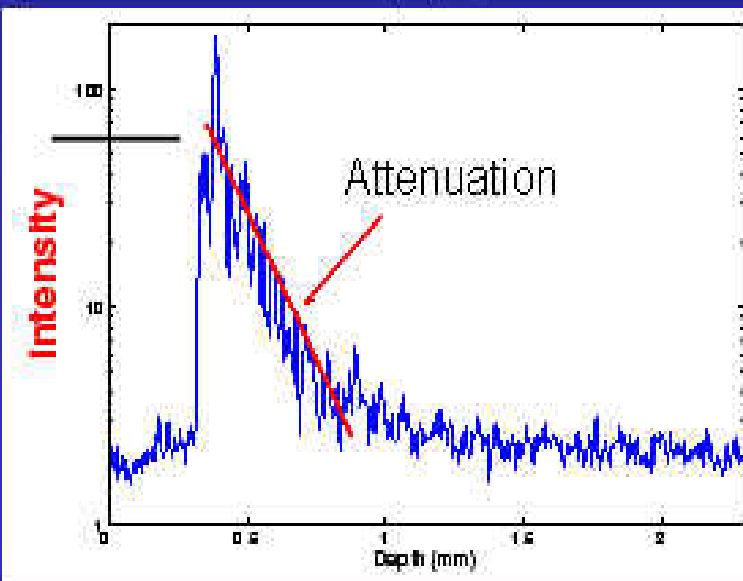
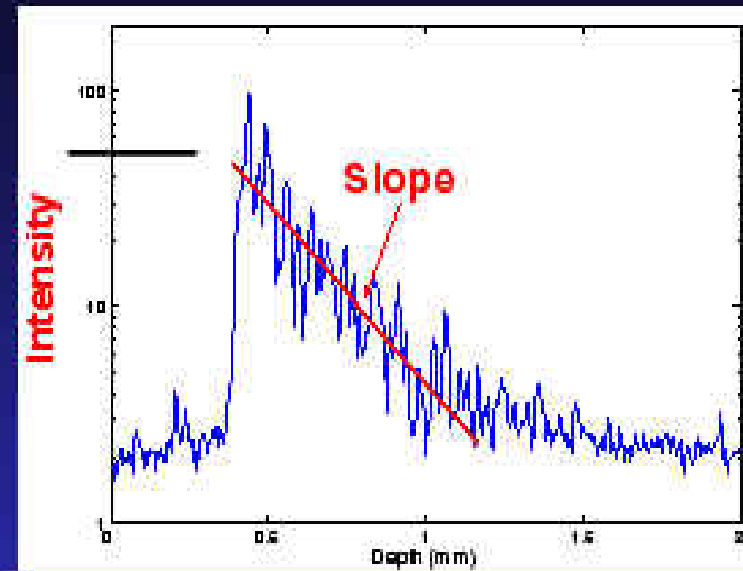
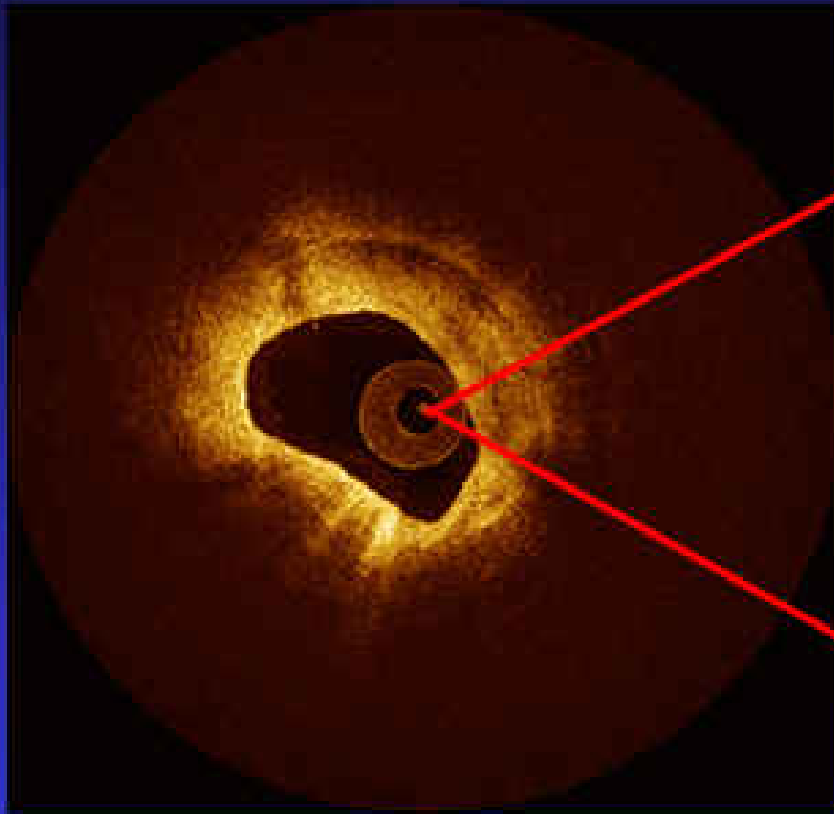
Tearney et al, JACC imaging 2008; 1: 752-61



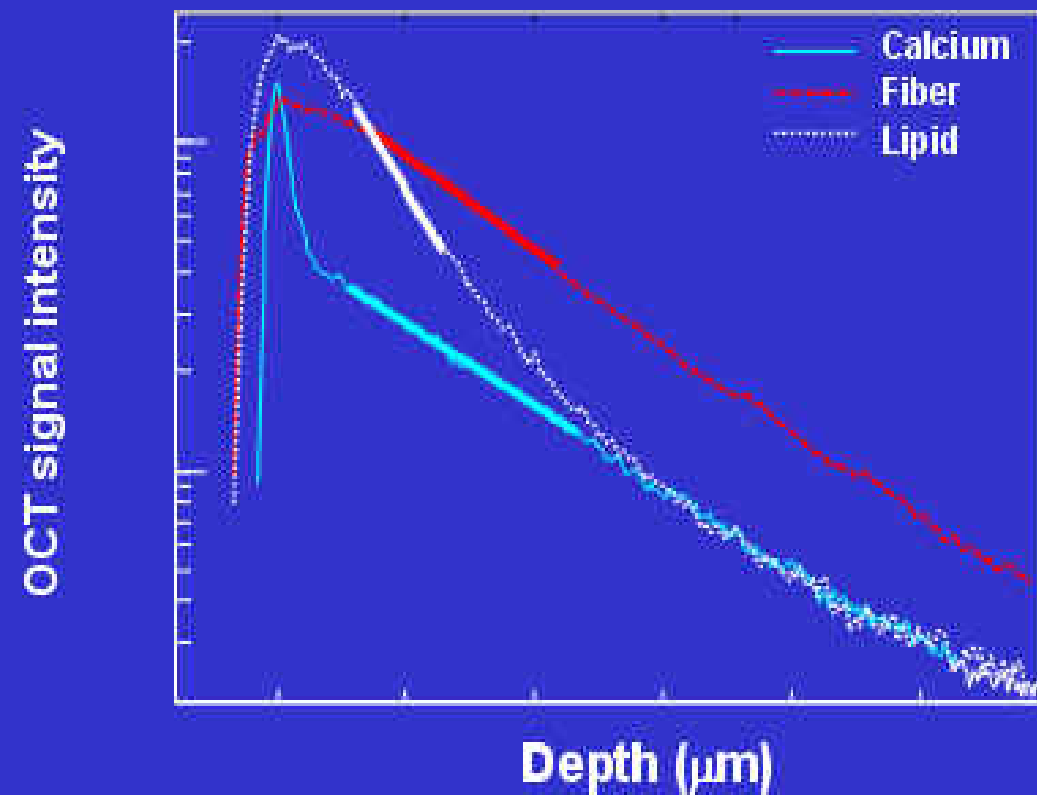
Wakayama Medical University

Basic optical physics of OCT is important for image interpretation

Brightness and Attenuation



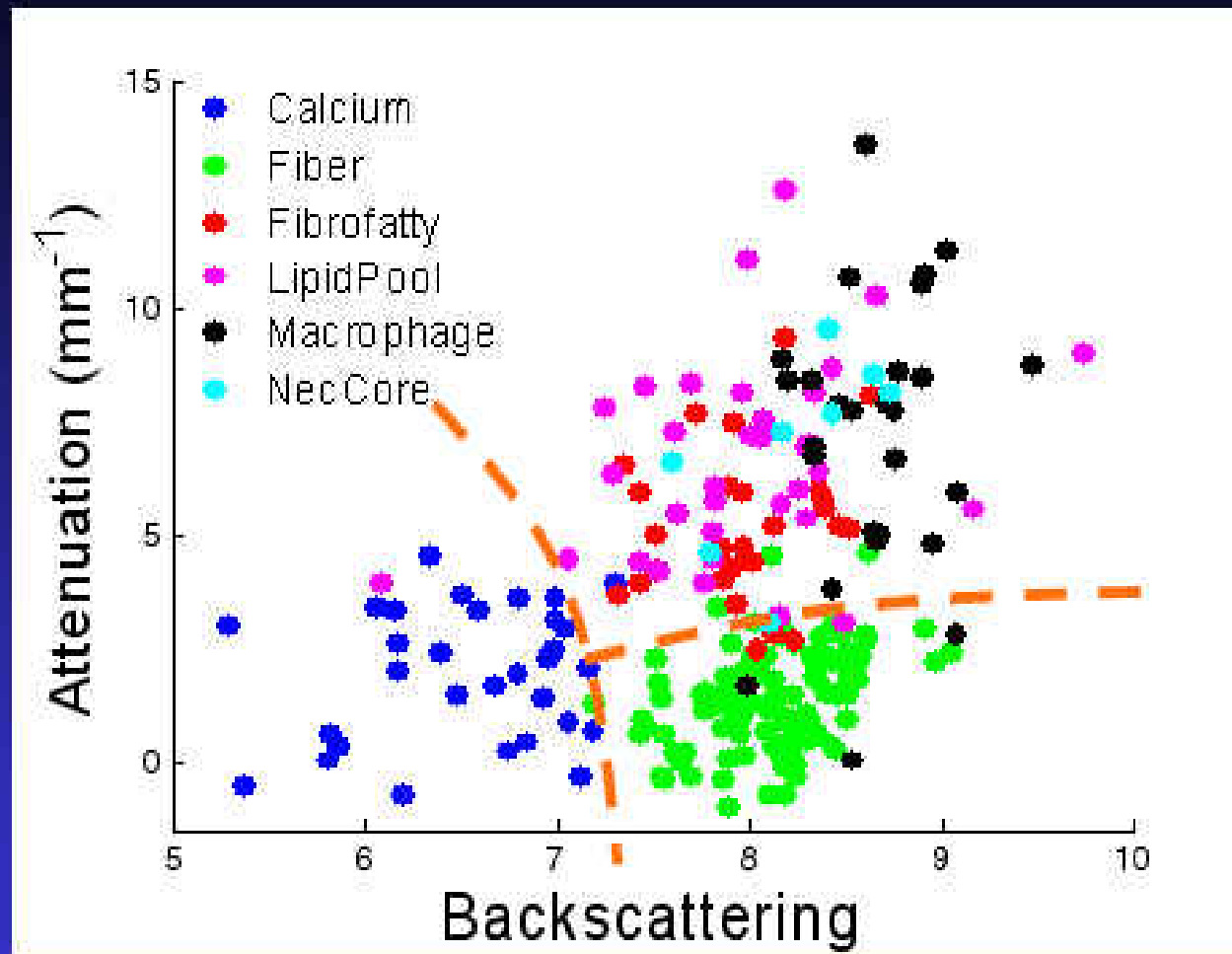
Quantitative Findings



Plaque type	Backscattering coefficient	Attenuation coefficient
Calcification	4.9 ± 1.5	5.7 ± 1.4
Fiber	19.2 ± 5.2	6.6 ± 0.7
Lipid	29.7 ± 6.4	14.9 ± 2.5



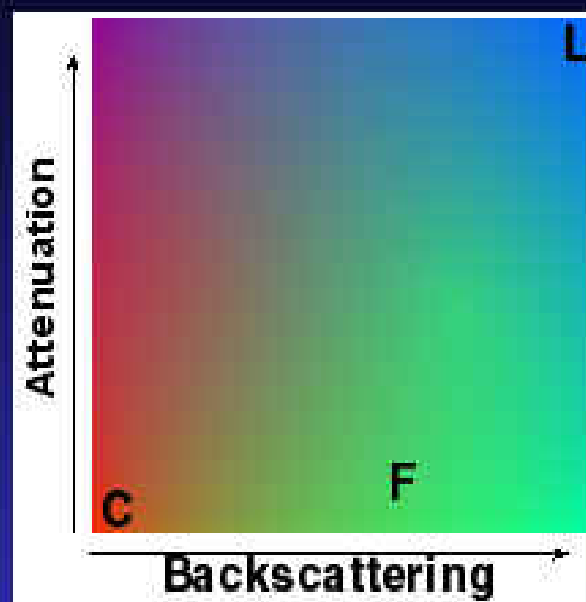
Measurements on Histology-Guided Regions of Interest



- Good separation among calcification, fiber and other
- Poor separation among fibrofatty, lipid pool and necrotic core
- Attenuation/backscattering is not a good measure for macrophage/foam cells

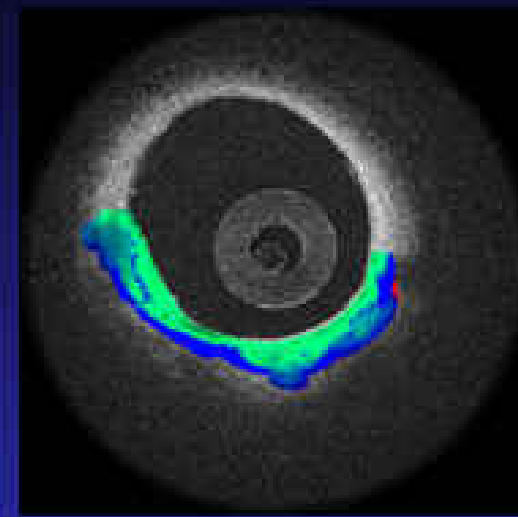


Colormap for combining backscattering and attenuation

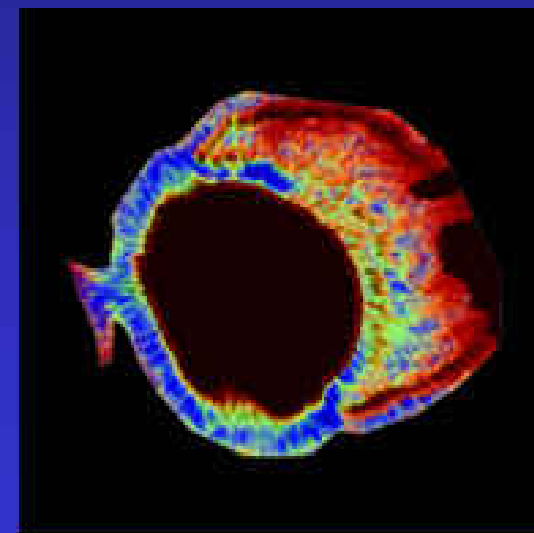
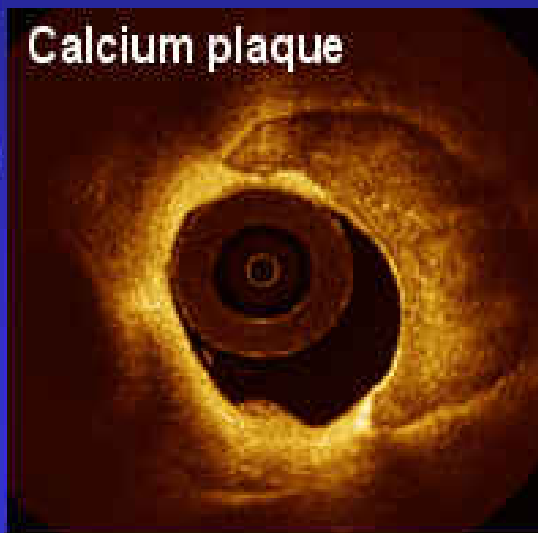


Colormap for combining
backscattering & attenuation

Lipid plaque

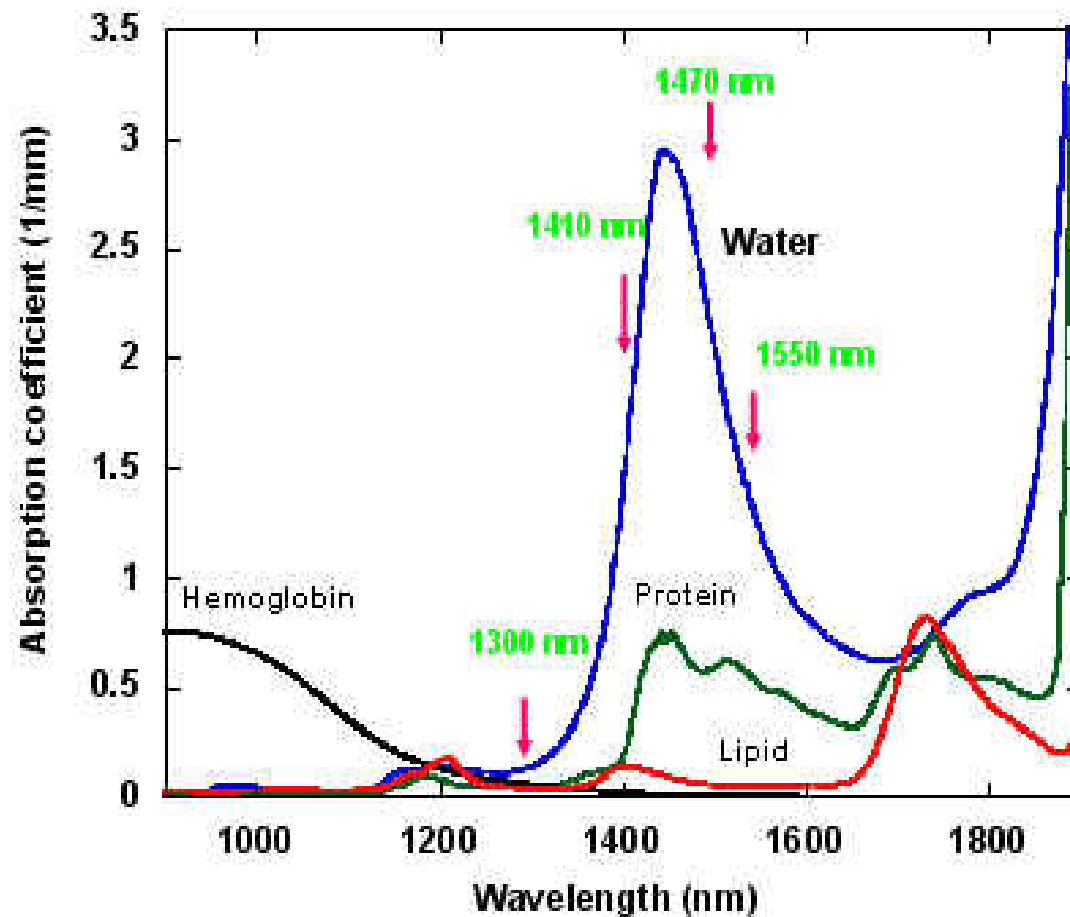


Calcium plaque



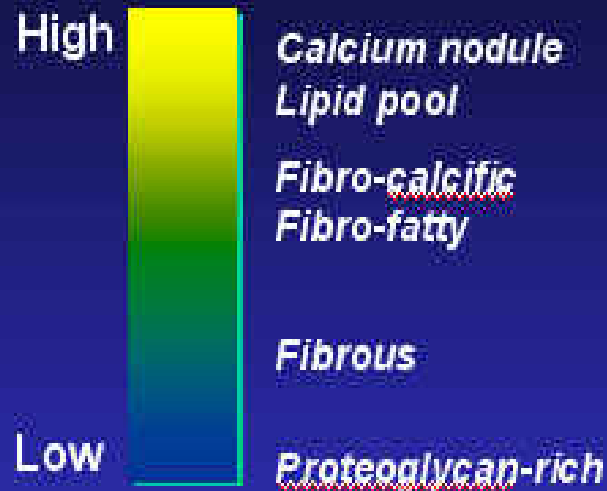
OCT spectroscopy

Most of the major biochemical constituents of arterial plaque have distinct NIR absorption spectra

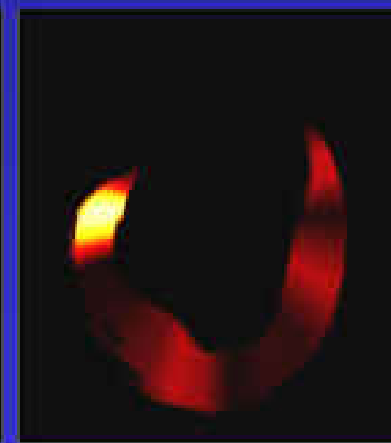
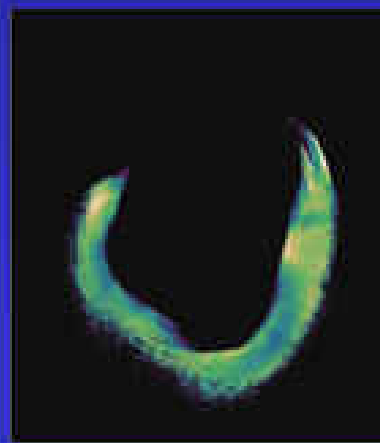
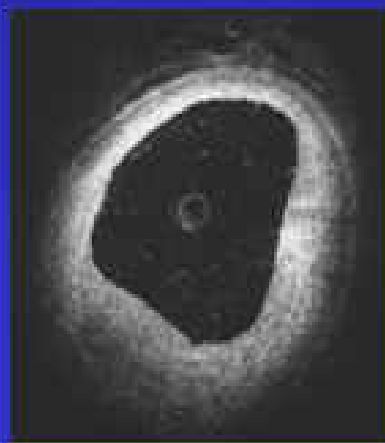
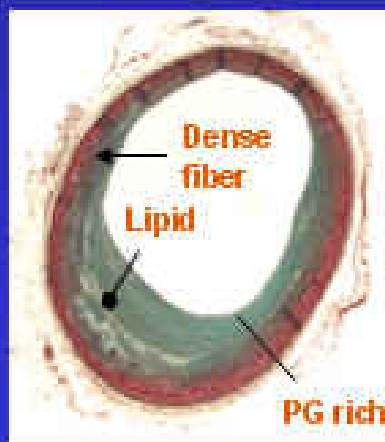


Plaque Characterization with Polarization and Spectroscopy

Spectroscopy



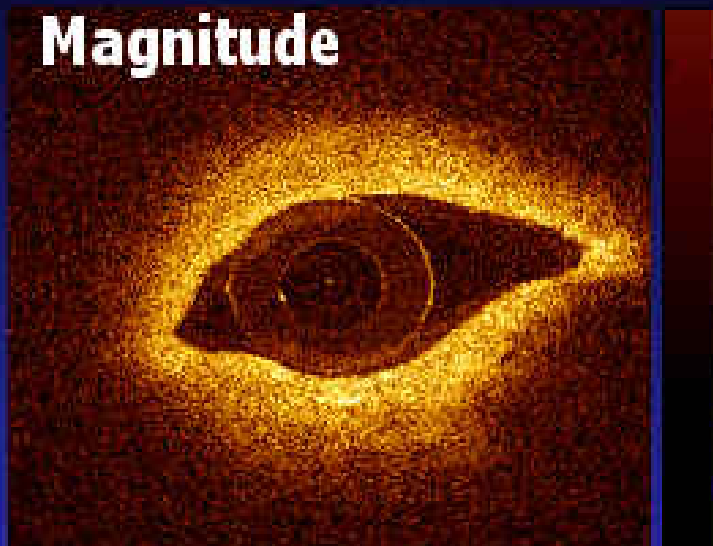
Birefringence



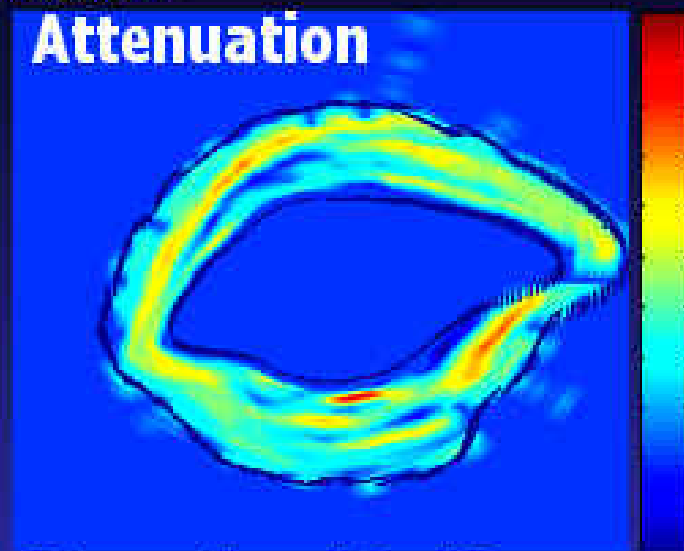
Example of early results (Lightlab Co.)

-before Histology validation-

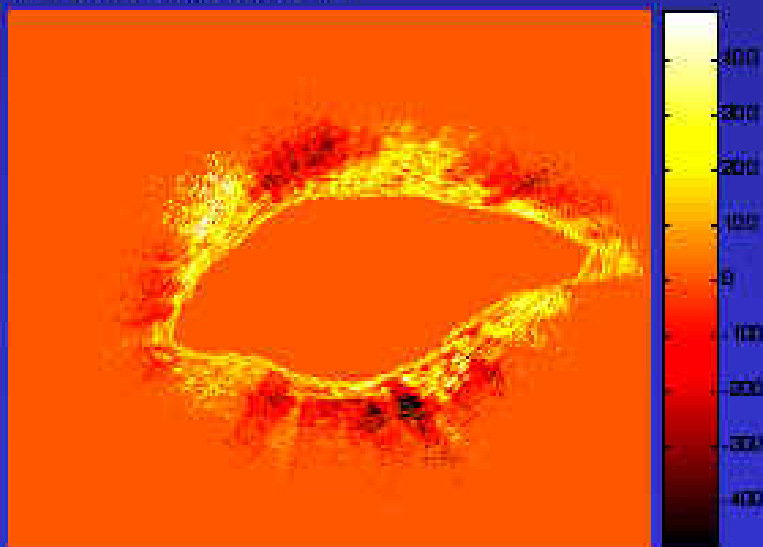
Magnitude



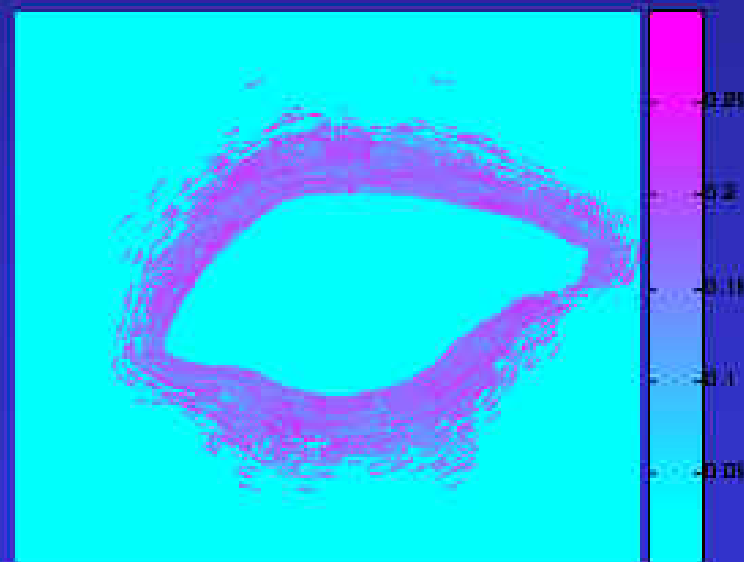
Attenuation



Polarization



Normalized Std Dev



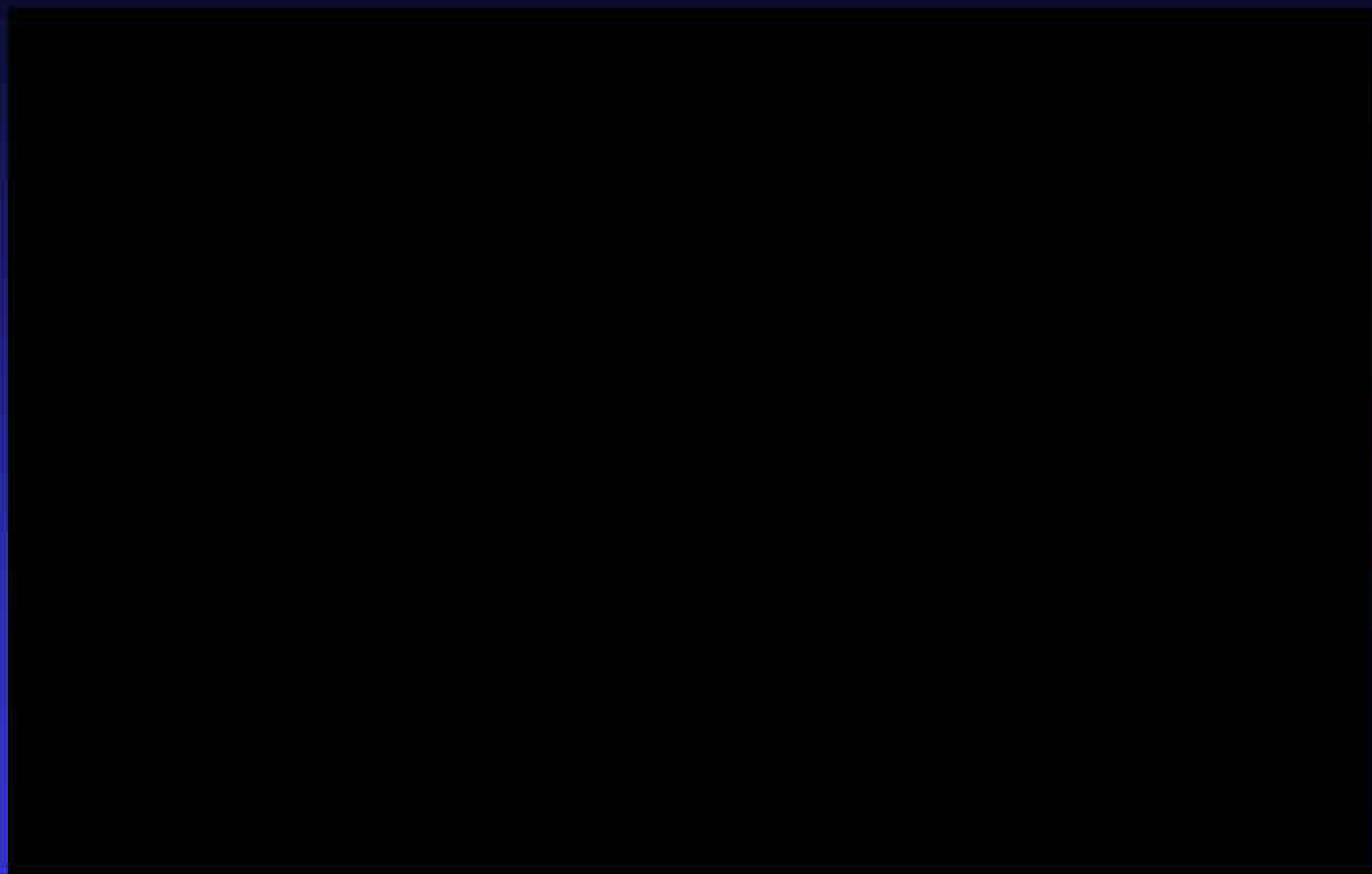
Conclusions

Higher frame rate (20 vs 100 frames/sec) ,
grater lines in one frame (240 vs 450 lines / frame) and
grater scan diameter (6.8 vs 8.2 mm) compared with TD-OCT,
FD-OCT may allow us to

- perform data acquisition without balloon occlusion and record longer length of image in a few seconds (5cm in 3 seconds).
- demonstrate proximal potion of each coronary artery and LM.
- obtain clear images even if the image catheter is markedly displaced in one side.

Analysis of several OCT signal parameters may allow us to
demonstrate color-corded images and interpret images easier.





Conclusions

By higher resolution ($10\ \mu\text{m}$) and superior ability of tissue characterization, OCT may allow us to

- demonstrate the results of PCIs precisely, including mal-appositions, tissue protrusion, small dissection immediately after stent implantation.
- estimate the long term results of PCIs in detail, including thin neo-intima formation, mal-appositions, thrombus formation late after stent implantation.
- assess the pathophysiology of coronary artery response in detail after DES deployment.



OFDI Catheter

- Structure of Drive Shaft similar to Terumo IVUS

	Imaging Window Profile	GW Diameter	Effective Length	Pullback Length
Terumo OFDI	2.4Fr(0.80mm)	0.014"	1370mm	150mm
Terumo IVUS <i>ViewIT</i>	2.6Fr (0.87mm)	0.014"	1300mm	150mm
BSC IVUS <i>Atlantis™ SR Pro2</i>	3.2Fr	0.014"	1350mm	150mm

Citation: <http://www.bostonscientific.in/>

OFDI catheter



ViewIT

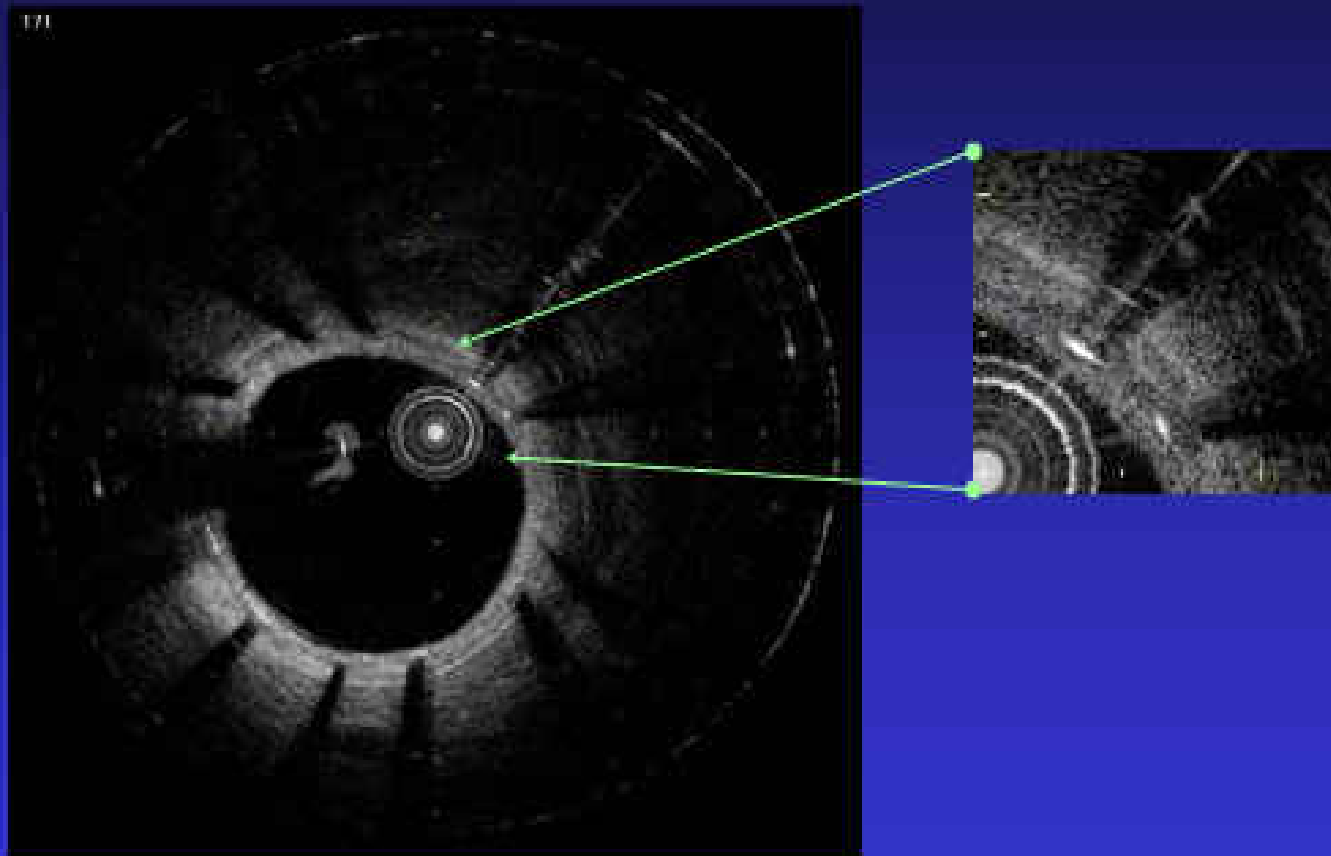


BSC Atlantis™ SR Pro2



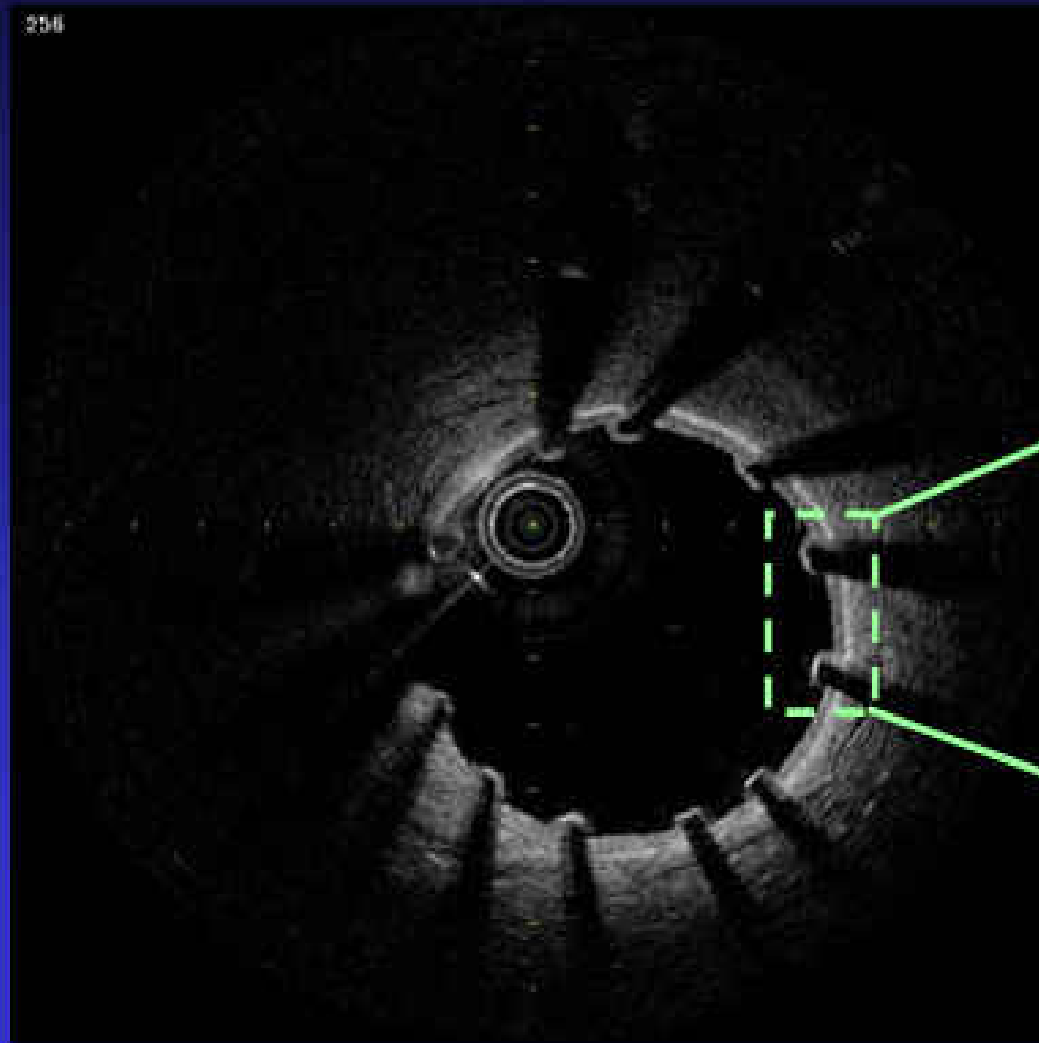
Nobori (Terumo DES) Pre-Clinical Study (April, 2008)

- Swine model 2 weeks after Stenting

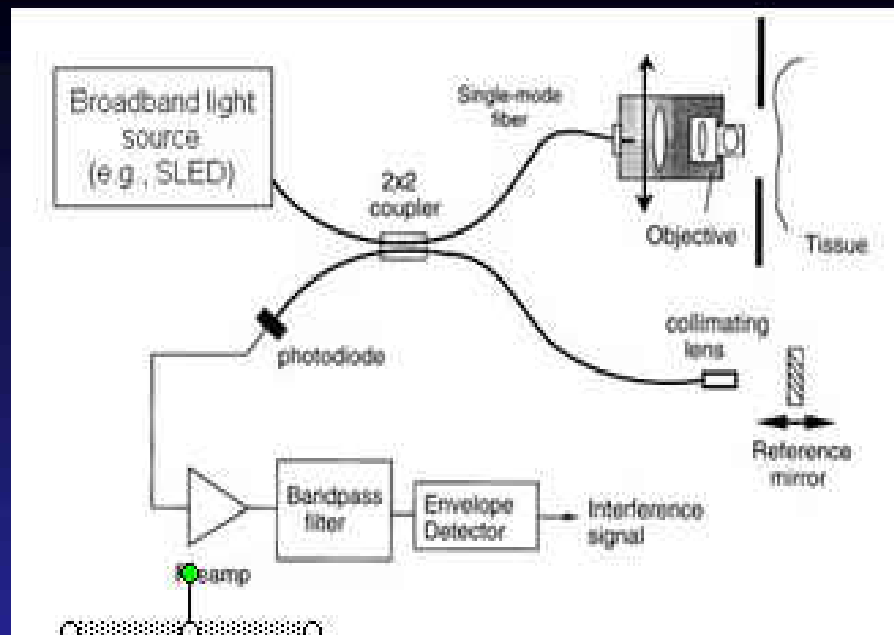


Nobori (Terumo DES) Pre-Clinical Study (April, 2008)

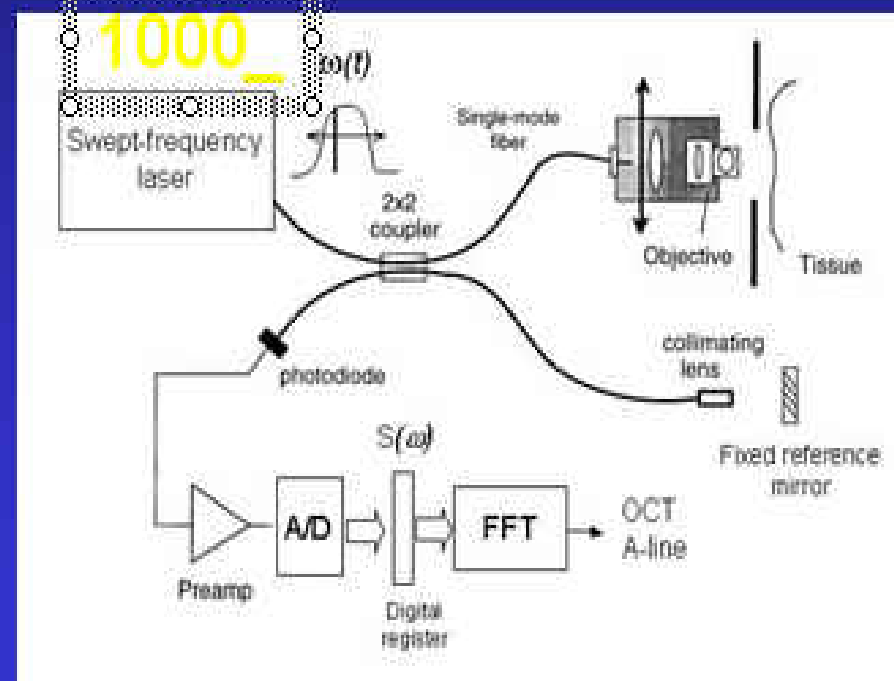
- **Swine model after Stenting**



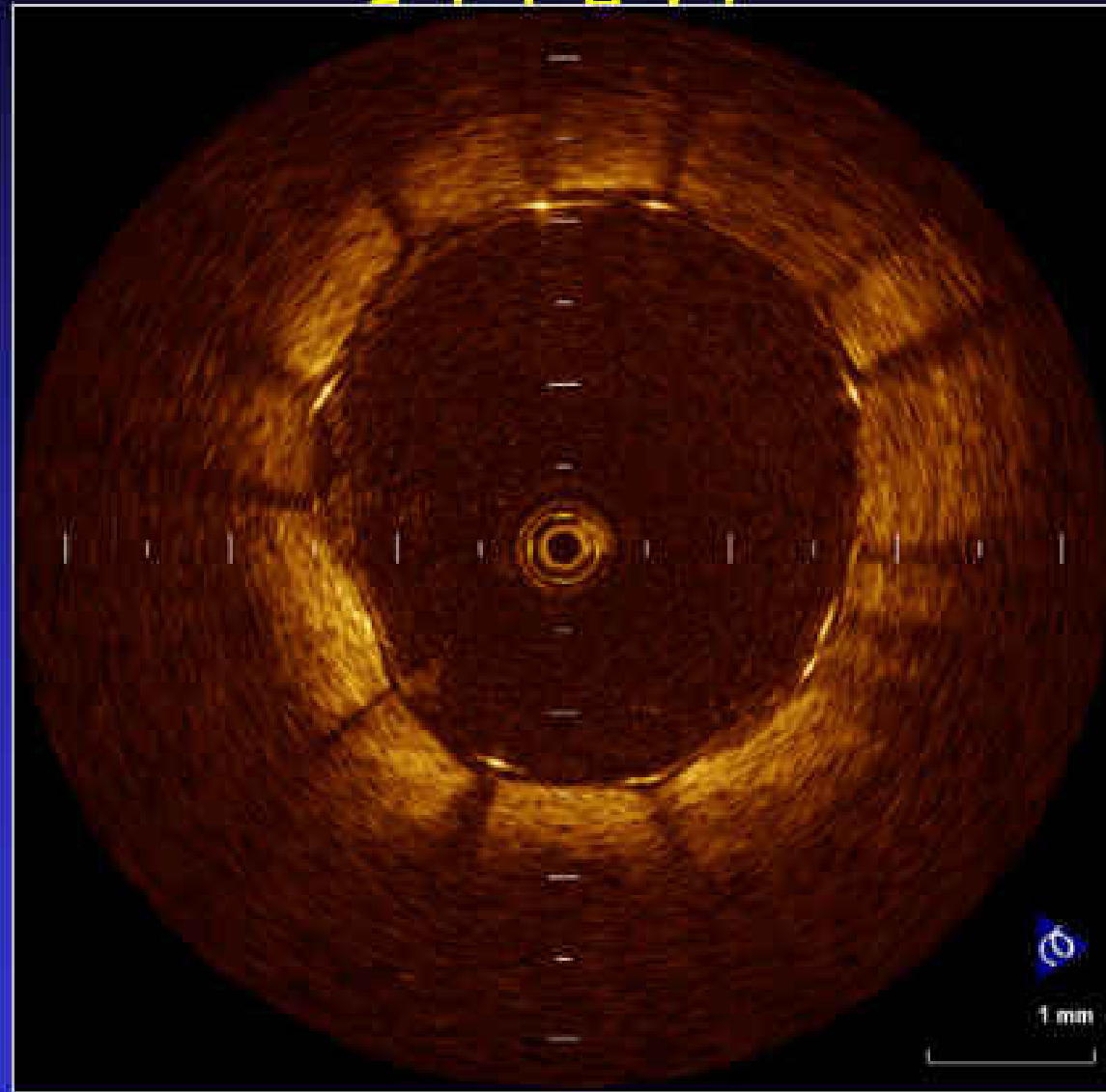
Time-Domain OCT



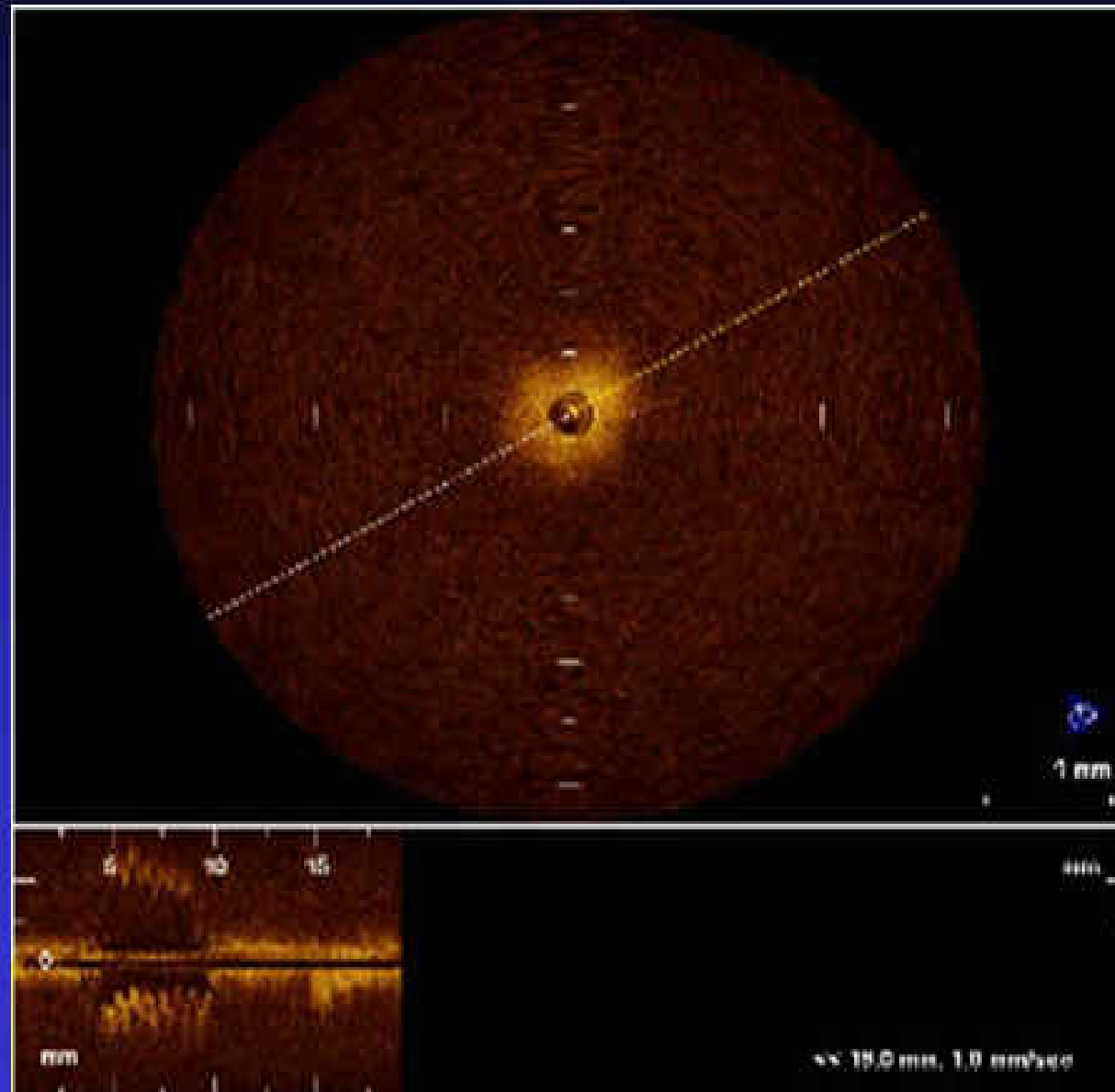
Freq-Domain OCT



Inadequate stent findings (Duraflex)



Low molecular dextrose 2ml/s for 5 sec by auto injection



Subjects and Methods

Study population

- ✓ Unstable angina pectoris (UAP; n=22)
- ✓ Stable angina pectoris (SAP; n=17)

Antiplatelet and anticoagulation therapy

- ✓ Oral aspirin (100 mg) and ticlopidine (200mg)
- ✓ Intravenous heparin (10,000 U/d for 48hrs in UAP)

Coronary intervention

- ✓ Sirolimus-eluting stent

OCT image Acquisition

- ✓ a 0.016-inch OCT catheter

(ImageWire®; LightLab Imaging, Westford, MA, USA)

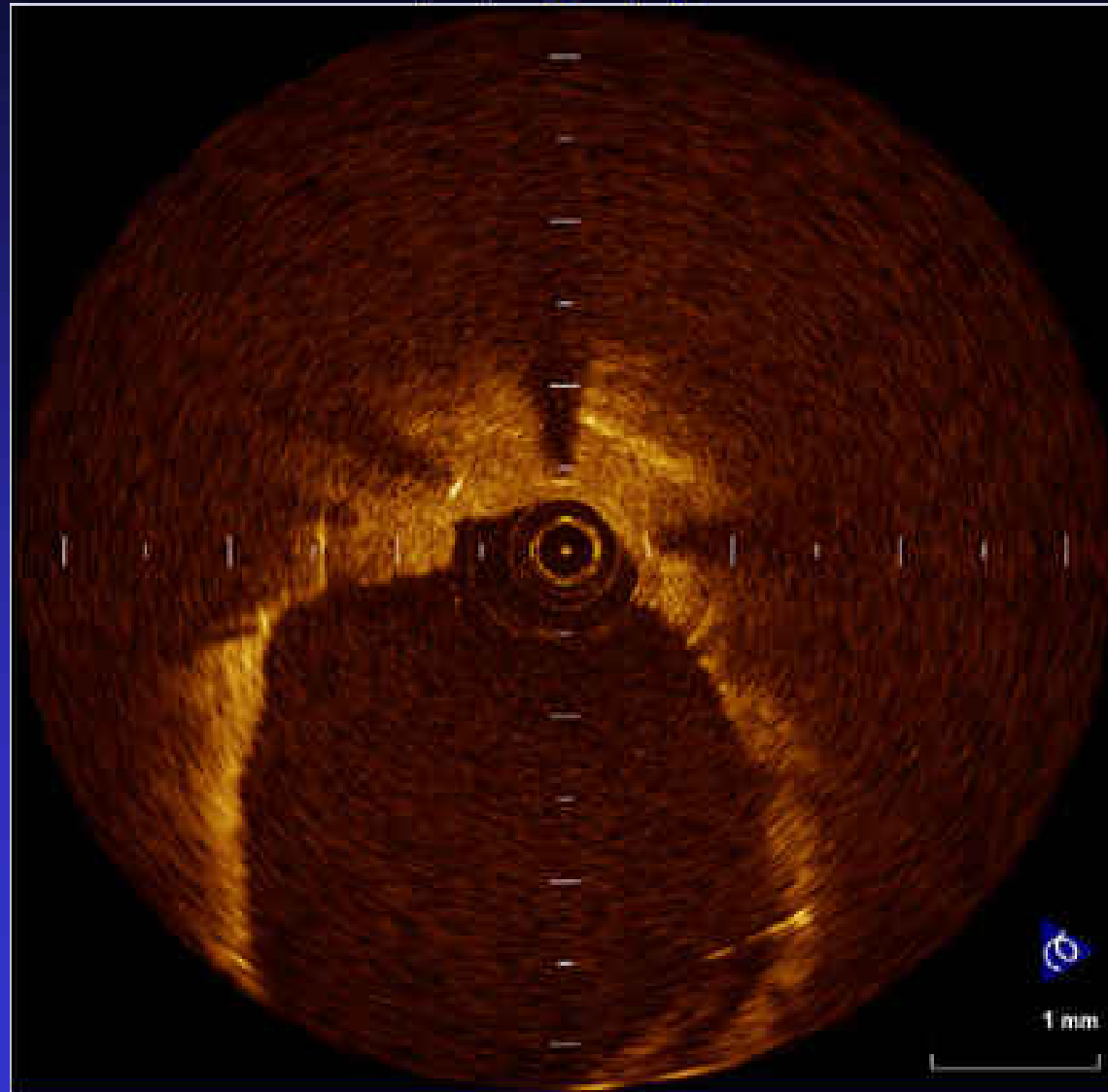


Stent profiles and OCT findings in UAP and SAP

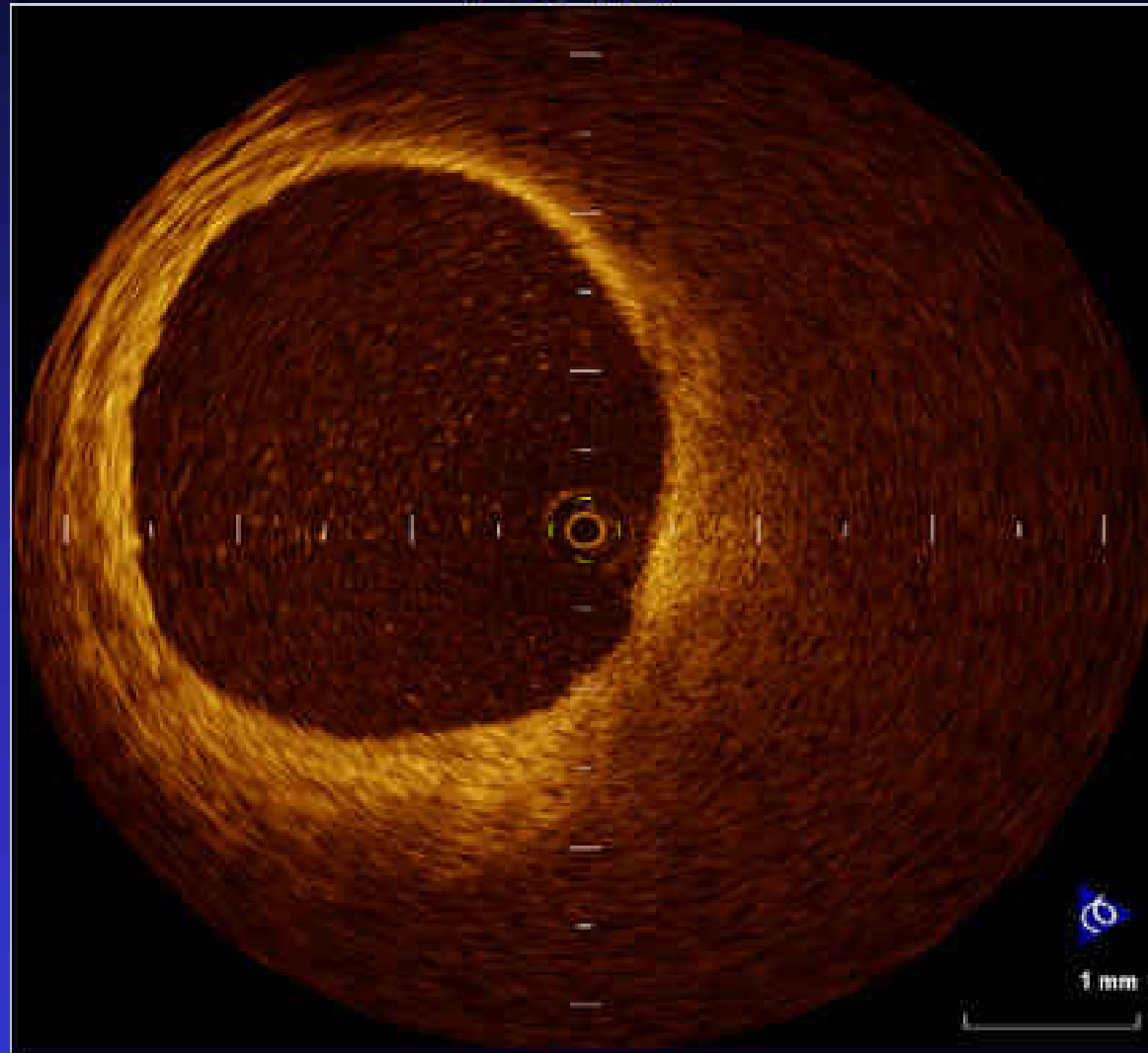
	UAP (n=22)	SAP (n=17)	<i>p</i>
SES diameter, mm	3.1±0.4	3.0±0.8	0.61
SES length, mm	21±4.8	22±4.3	0.50
Max. inflation pressure, atm	19±2.1	19±1.9	0.99
Postdilatation, n (%)	12 (55)	10 (59)	0.79
OCT minimum lumen site			
minimum stent area, mm ²	6.7±1.7	6.6±1.9	0.86
stent eccentricity	0.86±0.05	0.84±0.07	0.13



Inadequate stent findings (Dr iver)

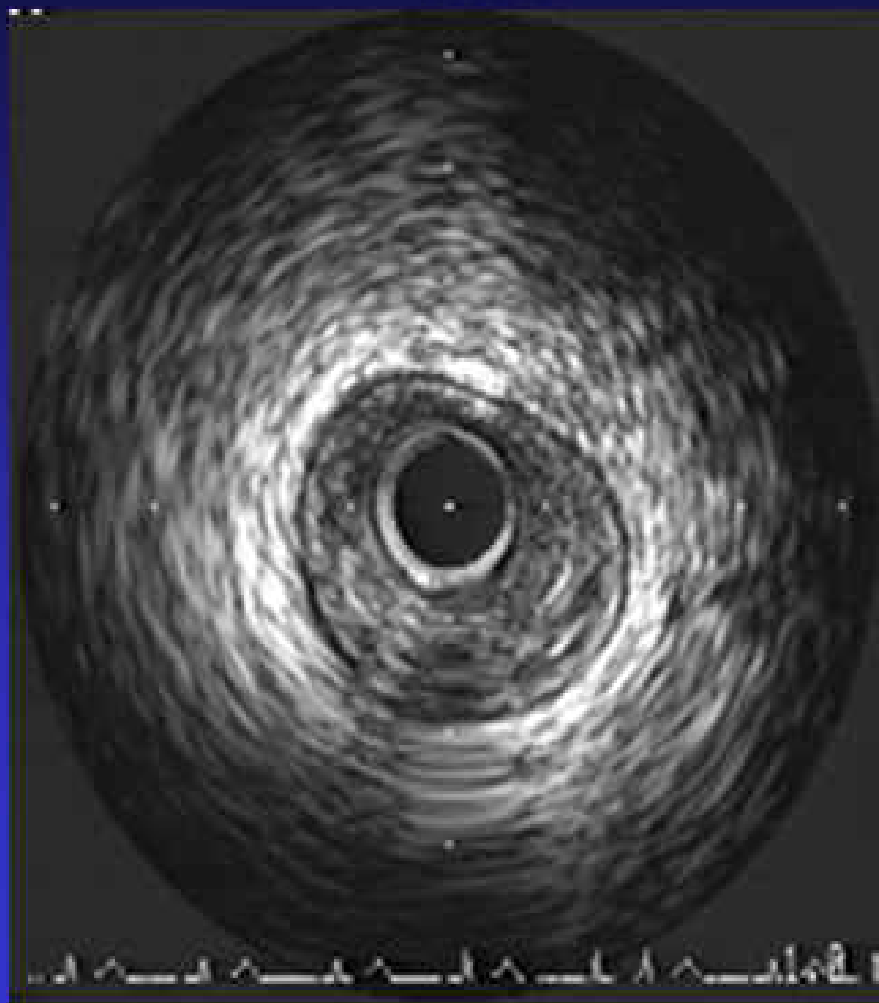


Inadequate stent findings (V i s i o n)

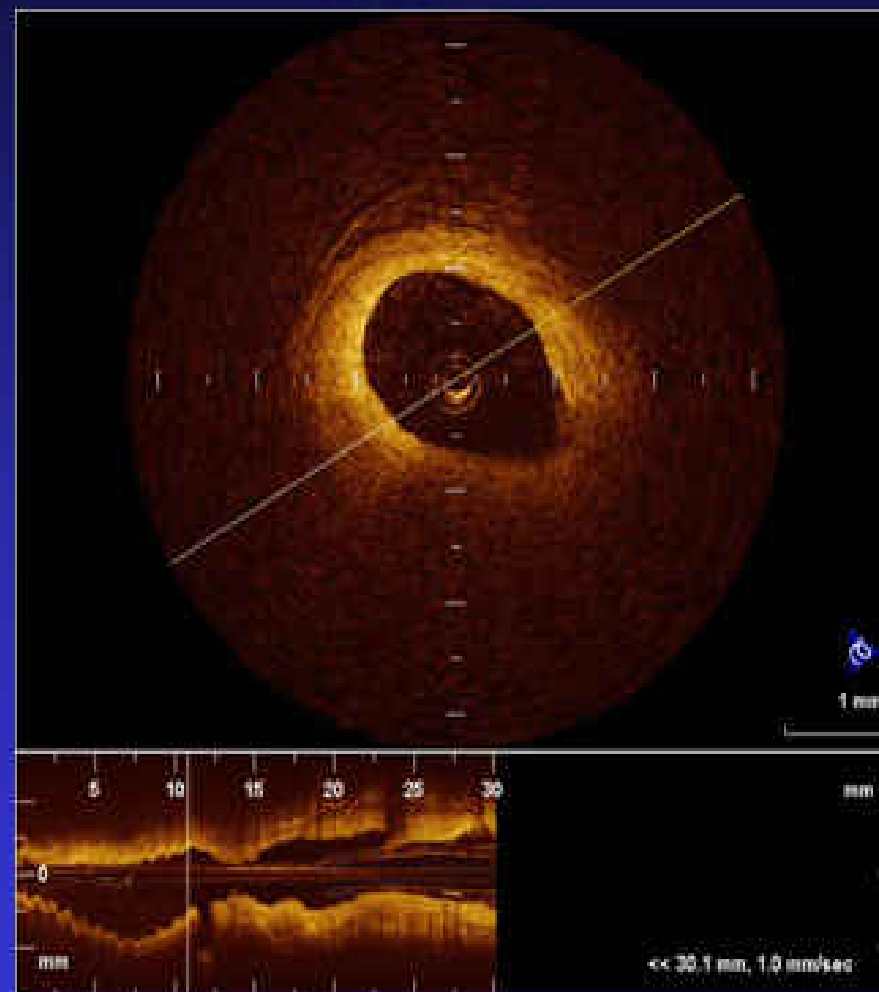


BMS instent restenosis

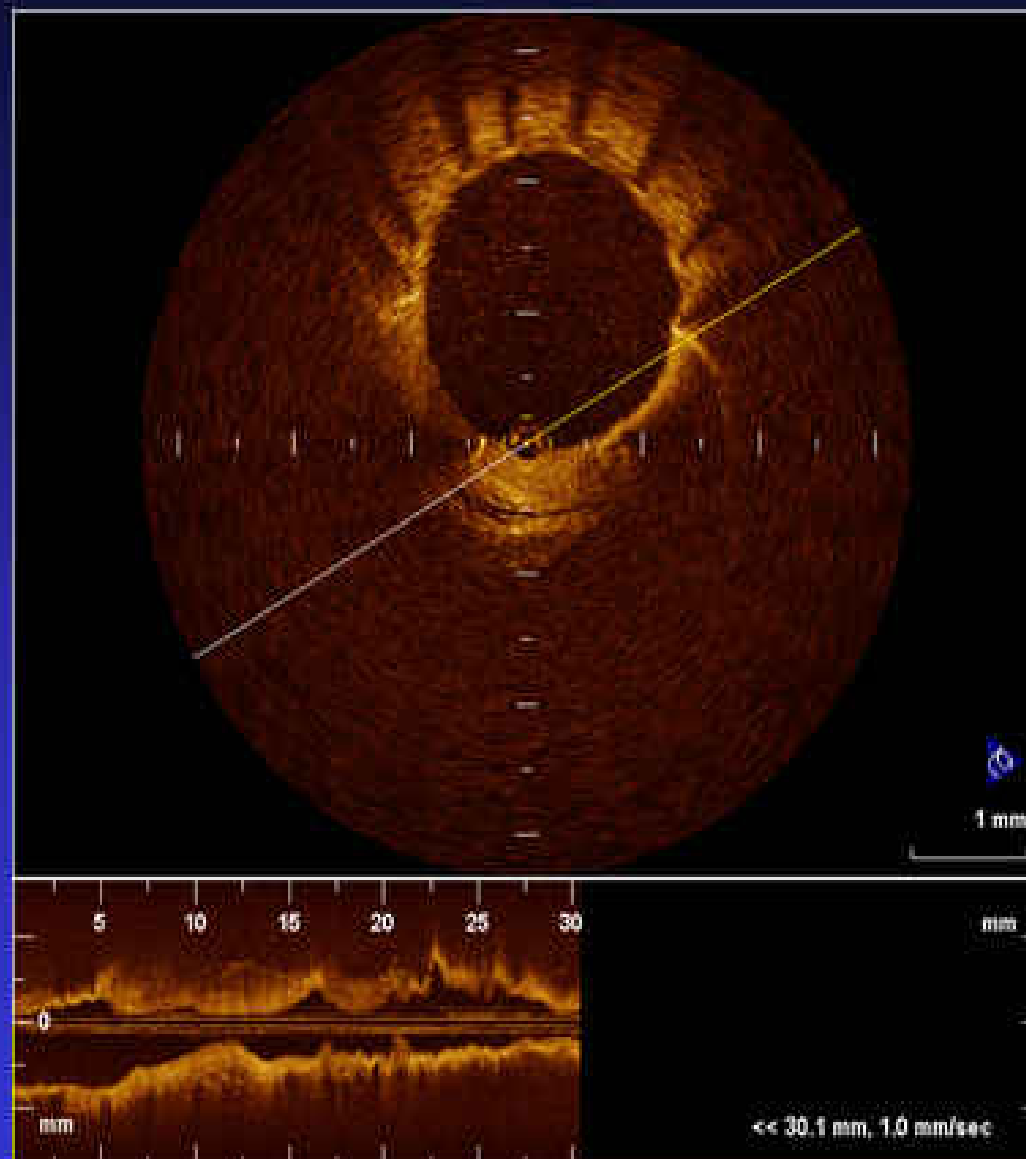
IVUS



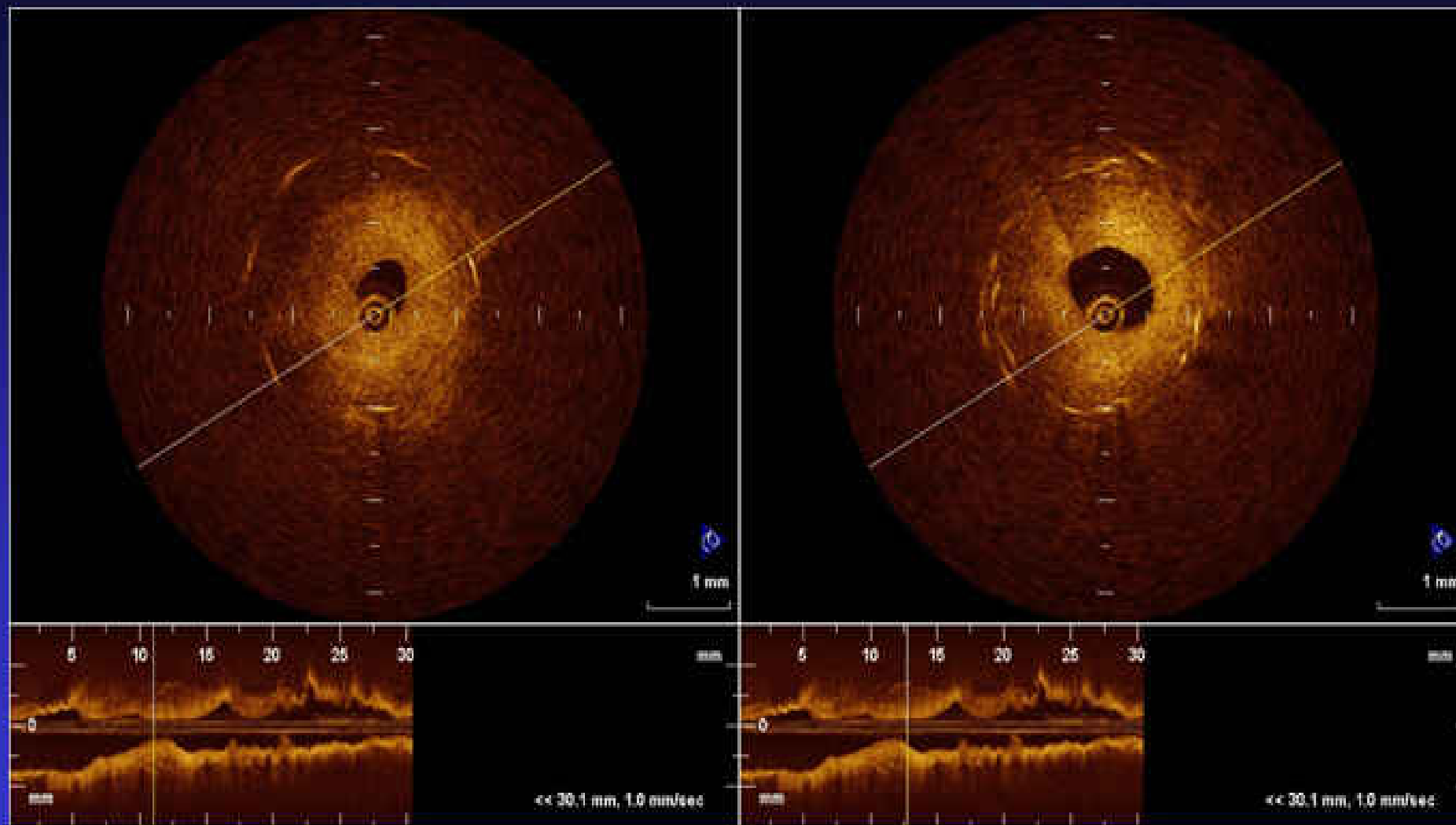
OCT



SES instent restenosis



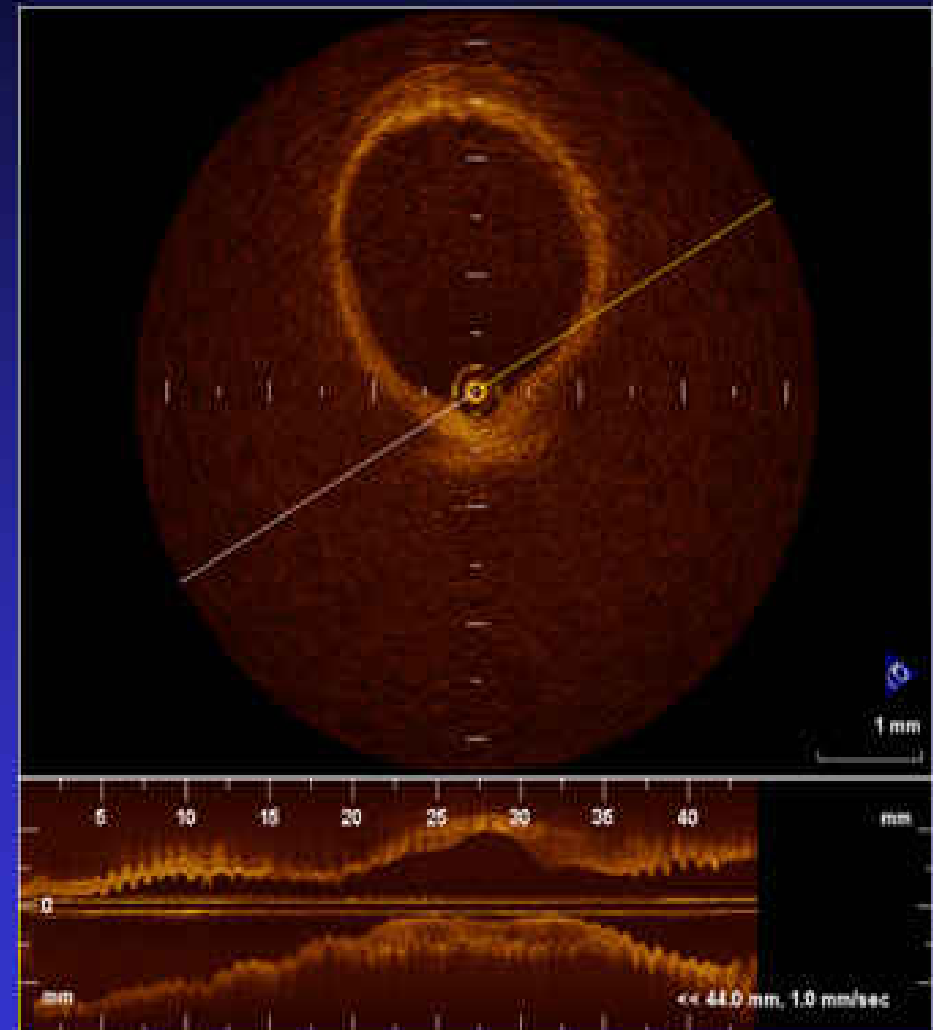
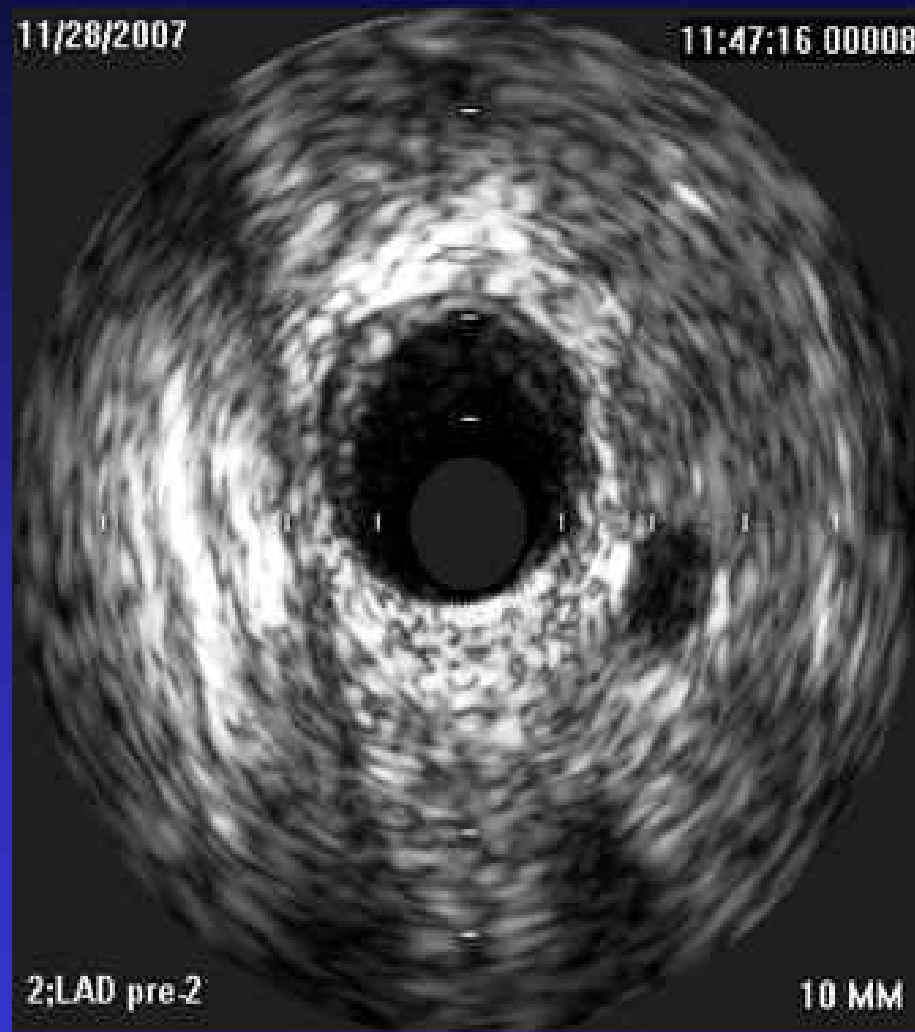
SES instent restenosis



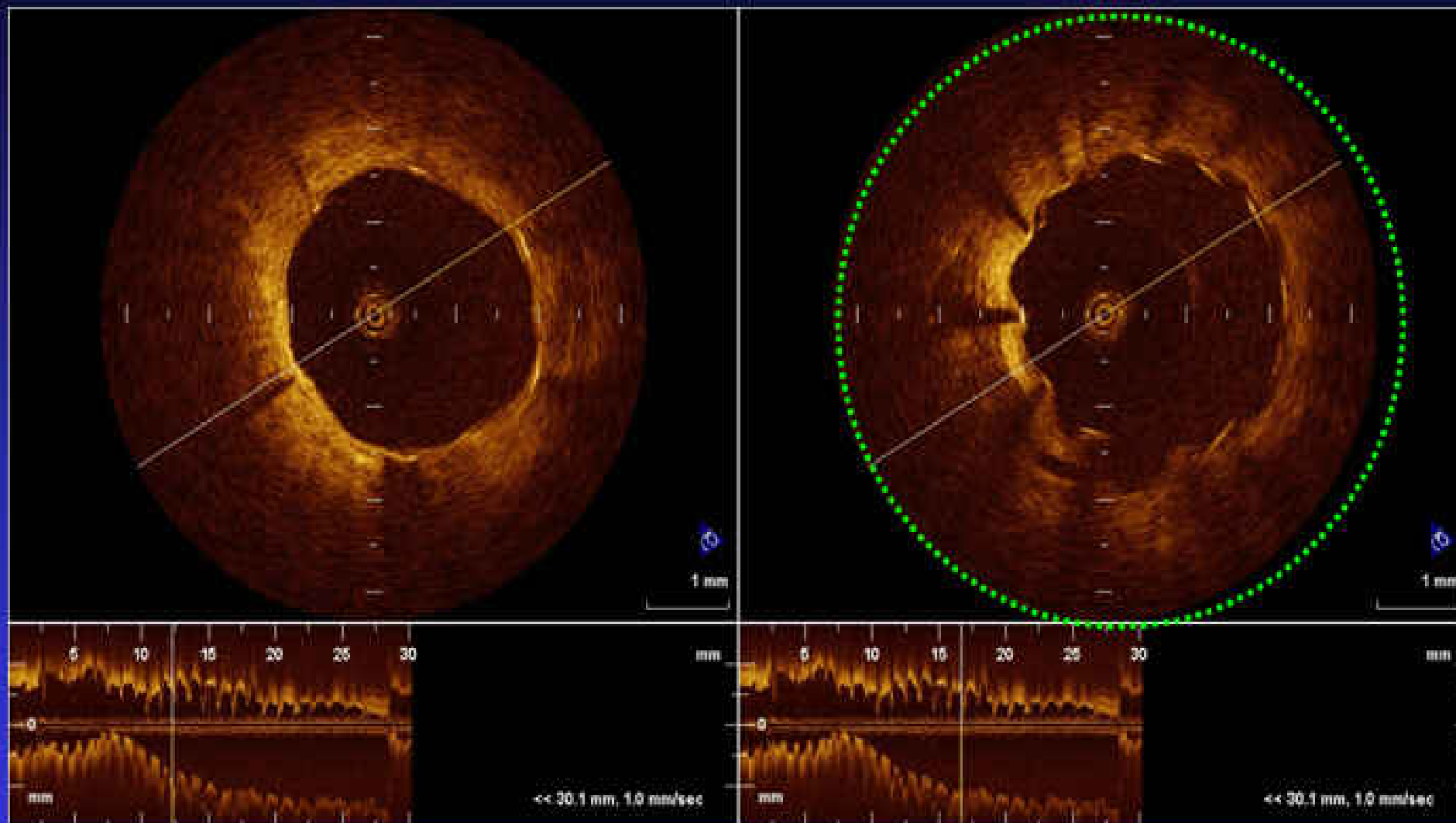
IVUS (PES)

11/26/2007

11:47:16 00008



Post-stent follow up



Wakayama Medical University



Wakayama Medical University

Difference between IVUS and OCT



IVUS



OCT

