INDUSTRIAL RESEARCH LIMITED

Optical measurements of retinal flow

February 2012

Techniques for flow measurement

- Retinal “functional imaging”
- OCT
- Doppler velocimetry
- Doppler flowmetry
- Laser speckle

Proven methods of measuring speed

Multiflash – The Retinal Function Imager

- *Tracks visible "irregularities" in vessels over repeated flash intervals*
- *Spot velocities (normal), micro-vasculature*

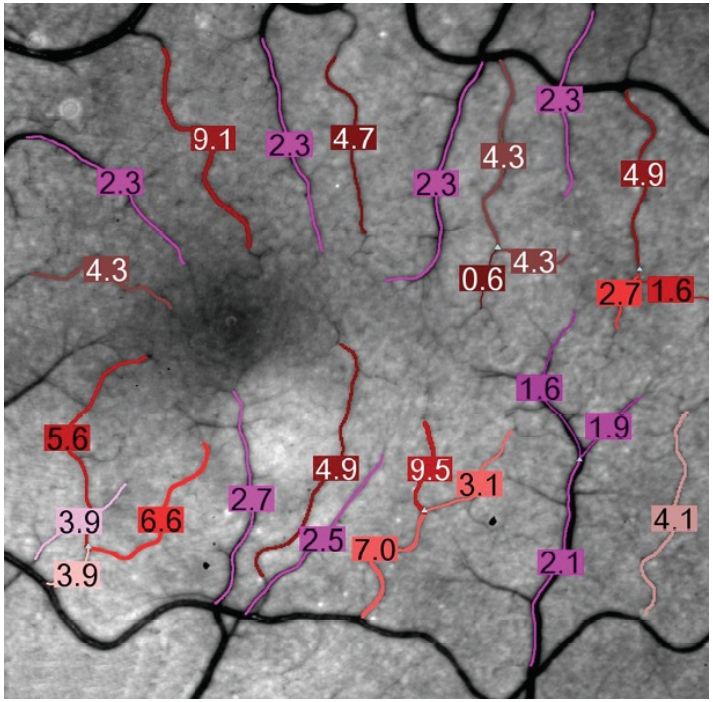
OCT - a believable measure of motion

- *Bragg scatter from wavelength-matched RI fluctuations*
- *Radial speed: Viewing angle correction important*
- *Capillary maps and vessel flows*

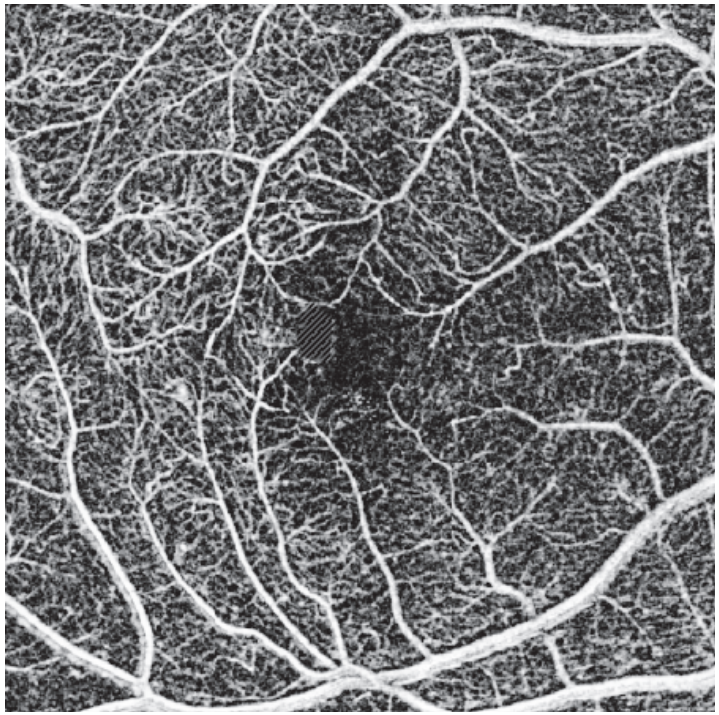
Retinal functional Imager

Optical Imaging Ltd, Israel

8 Xenon flashes ~ 20ms apart



Flow map - speeds



Micro vasculature

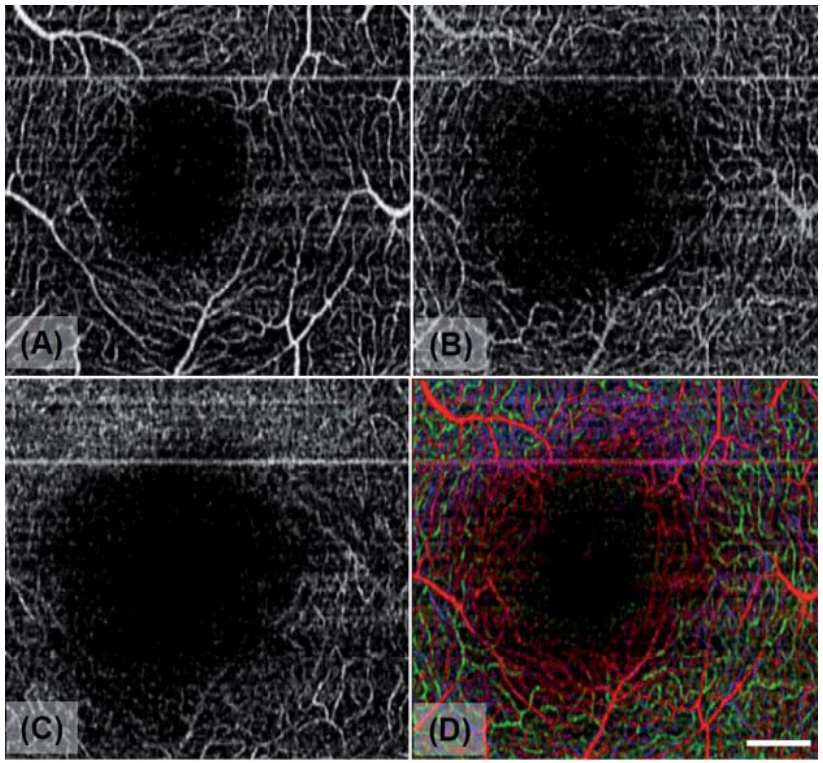
OCT 1:Vasculature visualization

Wang and An, JBO Lett. May 2011

Height above RPE:

>425μm

300-425μm



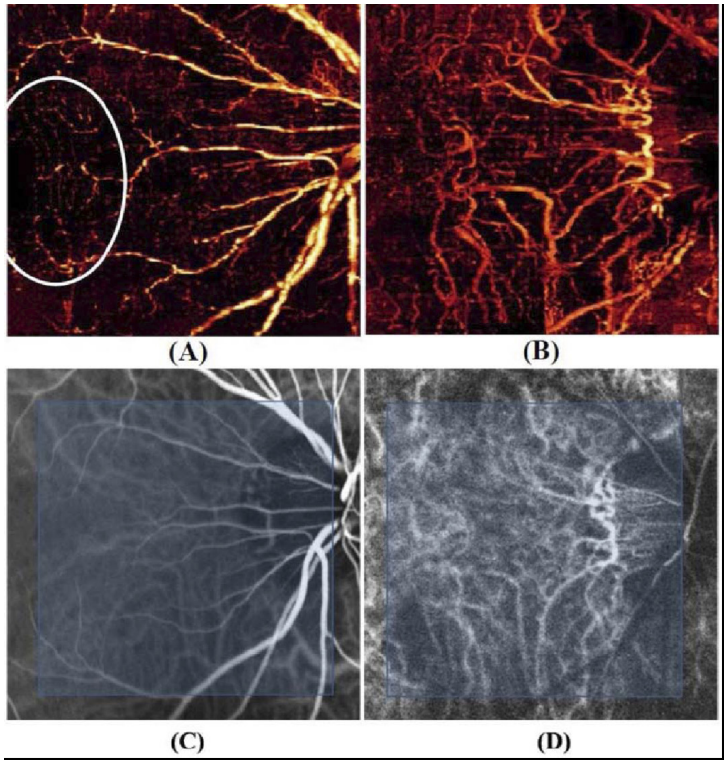
50-300μm

Superposition

Angiography and OCT flow mapped

Wang et al SPIE News 2010

16 OCT fields stitched,
choroid and retina



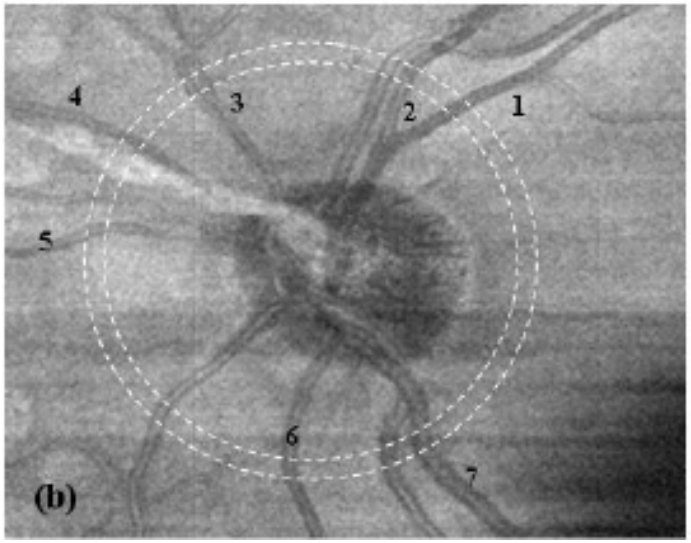
OCT 2: Doppler velocity at optic nerve

Wang et al, Optics Express March 2009

- *Two circular scans for acqisition speed*

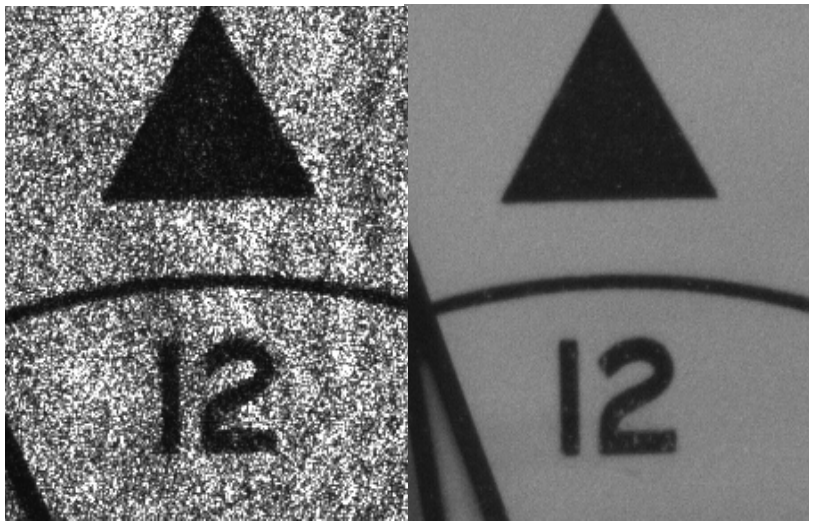
Mean speed 16.2 +-5.5mm/s

Total flow 33.2μL/min



Laser Illumination

- Images in laser light are grainy (speckled) because the returning light paths interfere at the camera (or the eye)



Coherent laser light *Incandescent*

Biospeckle and Doppler

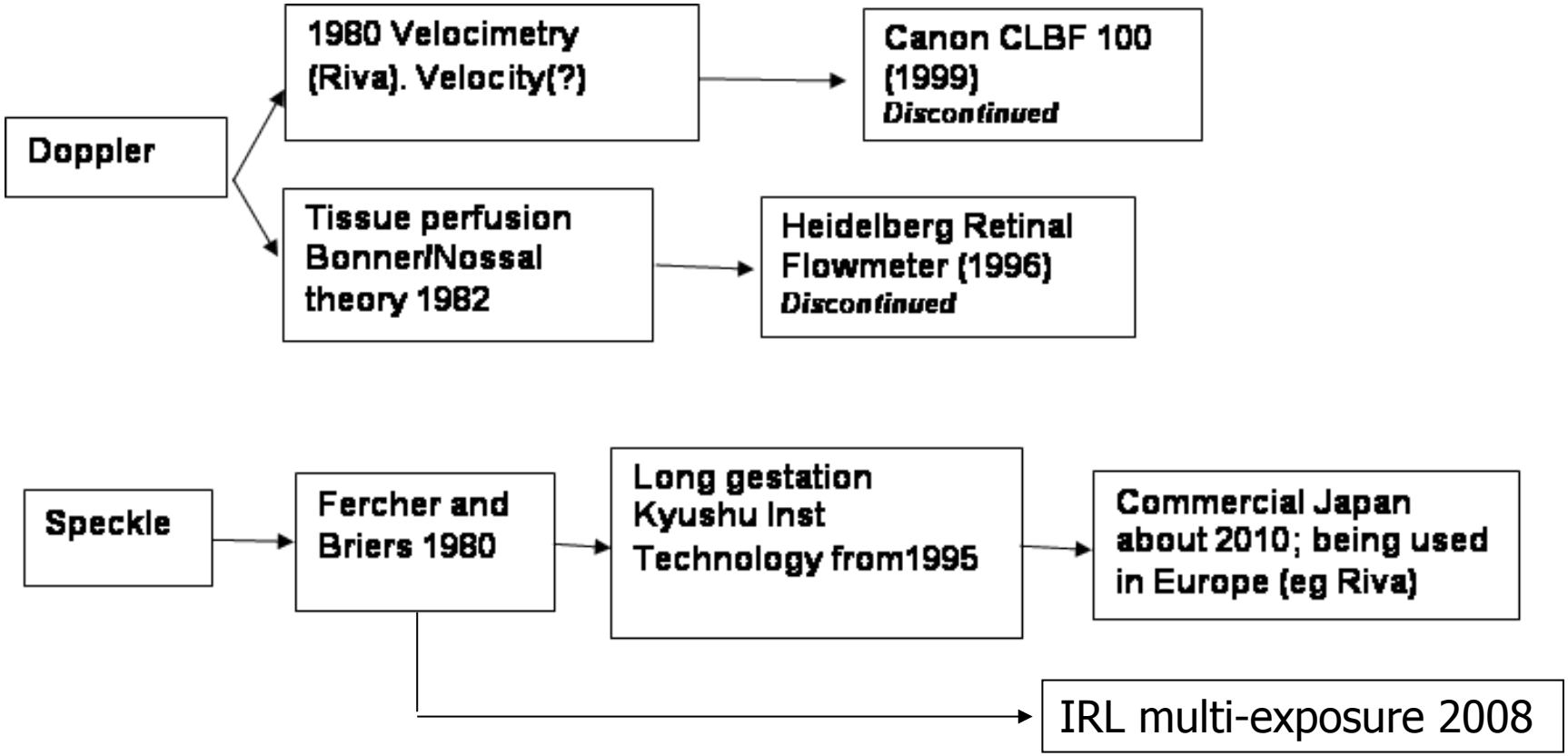
If some of the scatterers are in motion

- The interference pattern will change (twinkle)

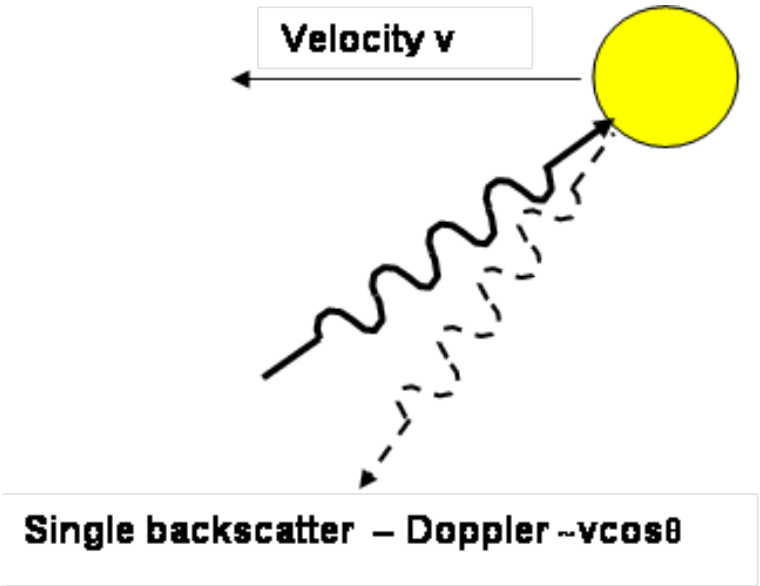
For a whole image	*For a point in the image*
"It's Biospeckle"	"Something is causing Doppler shift"

It's the same physics

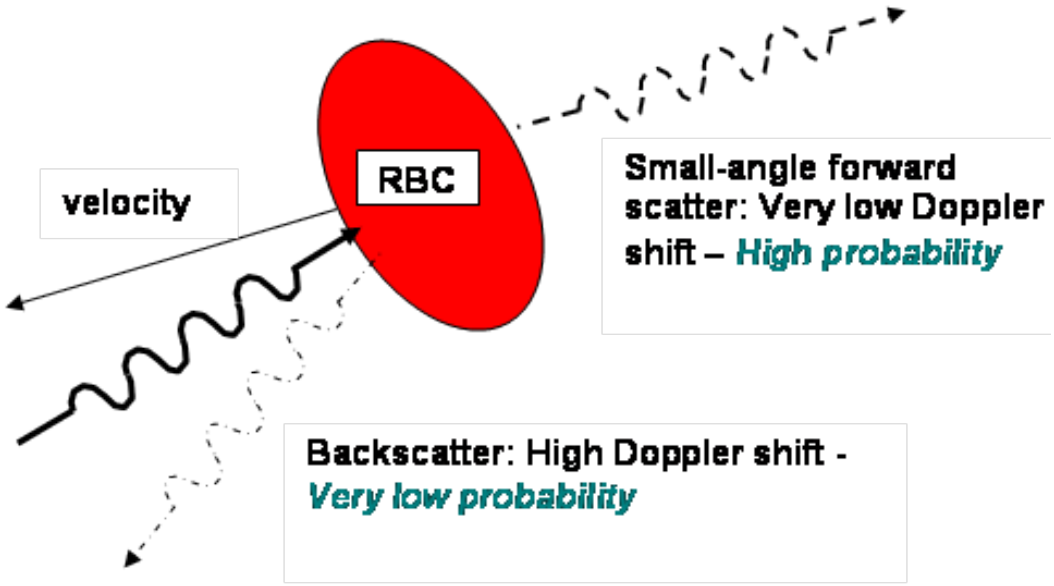
The fortunes of retinal instruments



Doppler shifts

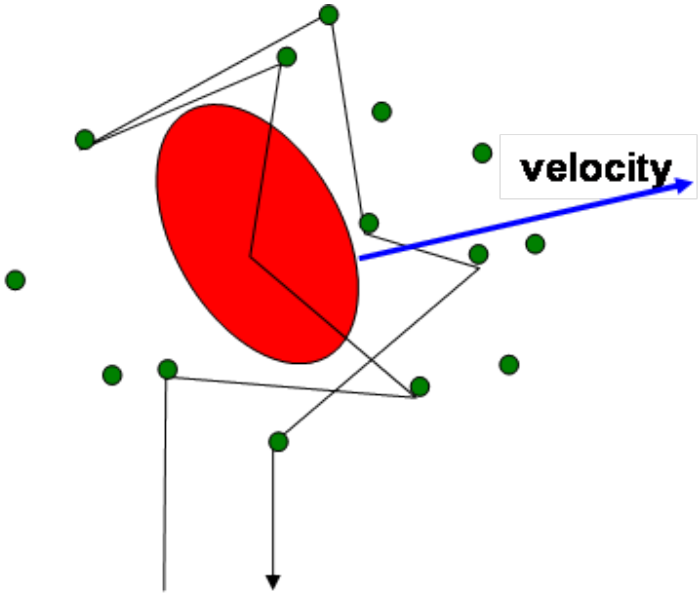


"Normal" scatter

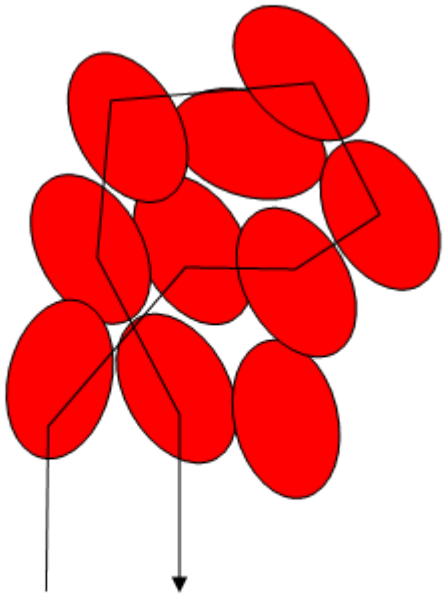


Angle-dependent scatter

Tissue and Vessel returns



Bonner Nossal tissue model (Heidelberg HRT)



Photon path returning within a blood vessel

Doppler v Speckle Perfusion

- Commercial perfusion instruments use Bonner-Nossal theory to interpret the Doppler power spectrum (and HRT)

- Speckle “contrast” easy but lacked quantitative equivalence to Doppler

- IRL contribution makes that equivalence and looks to be extendable to vessel flow

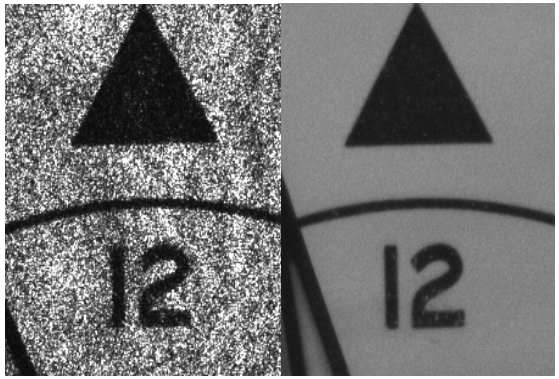
Speckle Contrast

- *A measure of the range of intensity within a speckled image*

No Biospeckle

Complete black to very bright

- highly grainy



Biospeckle (object twinkling)

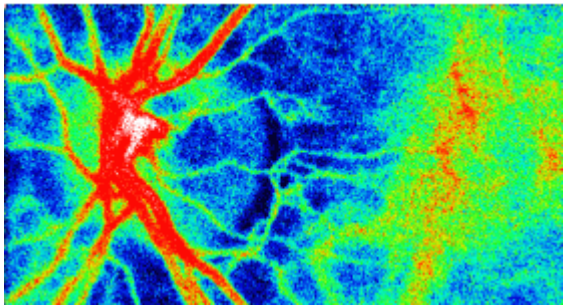
Contrast depends on the exposure

Long exposures blur totally - image is uniformly grey

Full field imaging

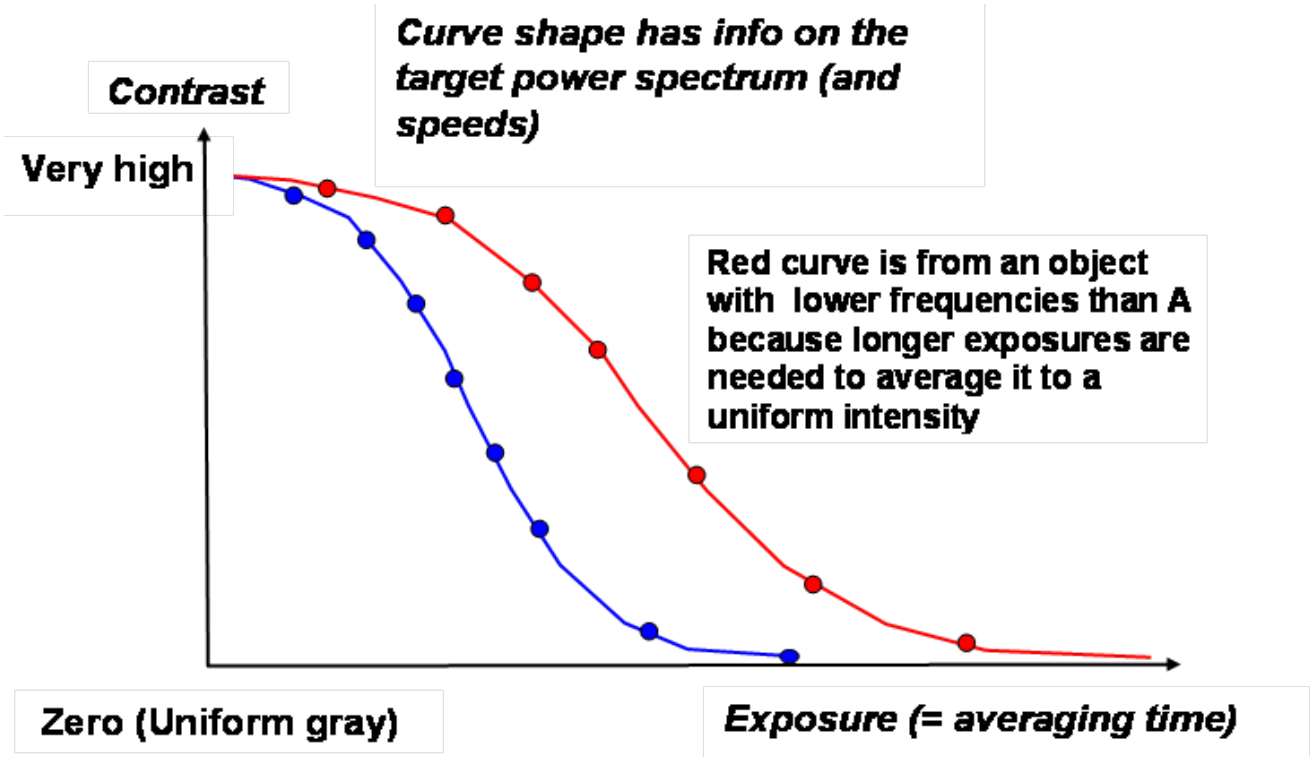
- A map of speckle contrast reveals spatial location of movement (vessels, perfusion)
- Unlike Doppler, data is collected within an exposure period
- A single exposure instrument released in Japan

Single exposure speckle
Softcare-Ltd, Japan



Real-time display of flow regions and flow "numbers"

Multi-exposure Speckle



Multi–Exposure Speckle
What Does it do?

- The shape of the blur curve gives information on the speeds of the scatters with no assumption of scatter mechanism

- Doppler spectrum follows from well defined blur curves; where relevant, tissue perfusion can be found