



Miniaturised dual-modality all-optical Laser Interstitial Thermal Therapy (LITT) and ultrasound imaging

Shaoyan Zhang,
Semyon Bodian, Edward Z. Zhang,
Paul C. Beard, Sacha Noimark,
Adrien E. Desjardins, and Richard J. Colchester

Introduction: Minimally Invasive surgery

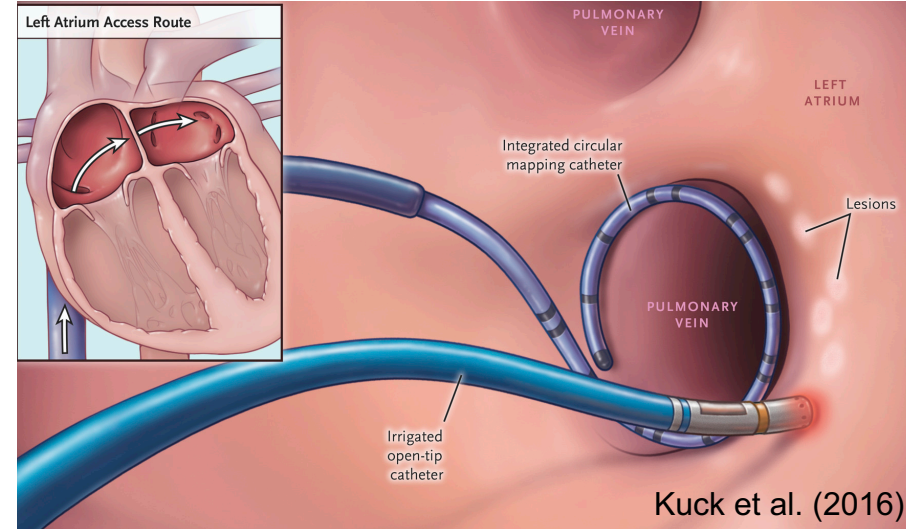
- Surgery where only small incisions are necessary
- Reduced scarring and discomfort
- Short hospital stay

Common manner are **ablation procedures**

- Atrial fibrillation
- Tumour resection (Brain, liver, kidney etc.)
- *etc.*

Ablation techniques:

- Radiofrequency, **Laser** and *etc.*



Introduction: Minimally Invasive surgery

- No direct line of sight of devices
- Current imaging: X-ray, OCT, MRI, Ultrasound
- Challenging to monitor the ablation procedure

All-Optical Ultrasound is promising for in situ ablation monitoring

- Lateral dimensions < 1 mm
- Real-time and high-resolution imaging
- Immune to electromagnetic interference
- Low cost



Introduction: All-Optical Ultrasound (OpUS)

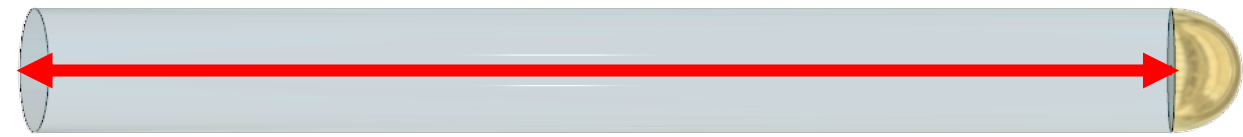
Ultrasound imaging using two fibre-optics;
one to transmit ultrasound and one to receive
ultrasound

Transmission: Composite coated fibre

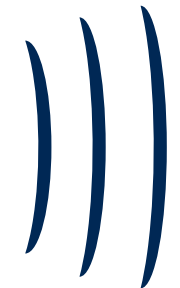


Colchester, R. J. *et al.*, *Appl. Phys. Lett.* **104**, 173502 (2014).

Reception: Plano-concave micro-resonator



Guggenheim, J. A. *et al.*, *Nat. Photonics* **11**, 714–719 (2017).



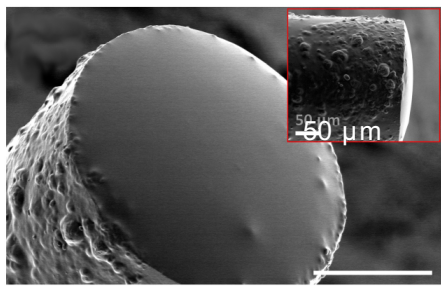
Transmission:

Reception:

Introduction: All-Optical Ultrasound (OpUS)

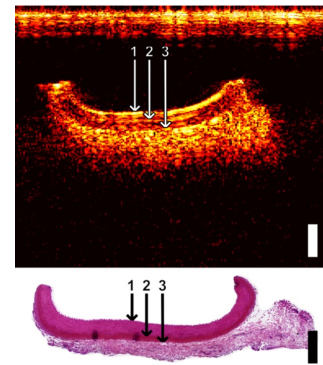
[1] Optical Transmitters

Noimark et al. *Adv. Funct. Mater.* (2016)
doi:10.1002/adfm.201601337



[2] 2D B-mode

Colchester et al. *Biomed. Opt. Express* (2015)
doi:10.1364/BOE.6.001502



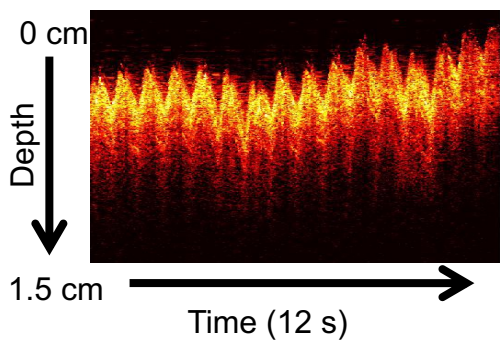
[3] Handheld OpUS probe

Alles et al. *Ultrasonics* (2021)
10.1016/j.ultras.2021.106514



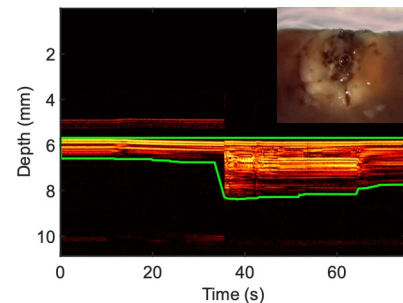
[4] M-mode

Finlay et al. *Light Sci. Appl.* (2017)
doi:10.1038/lsa.2017.103

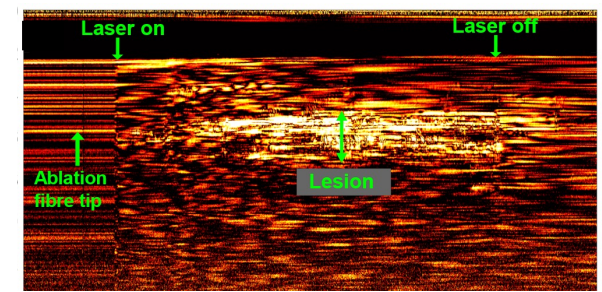


[5] Laser ablation monitoring

Zhang et al. *Comms. Eng* (2022)
doi:10.1038/s44172-022-00020-9

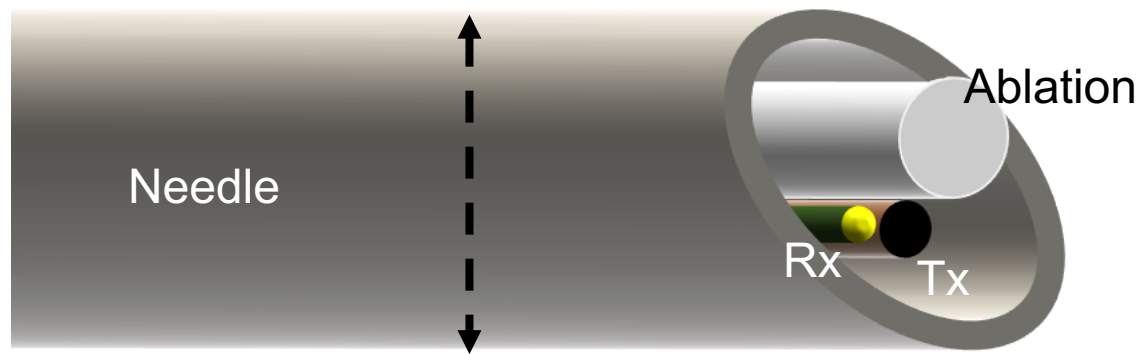
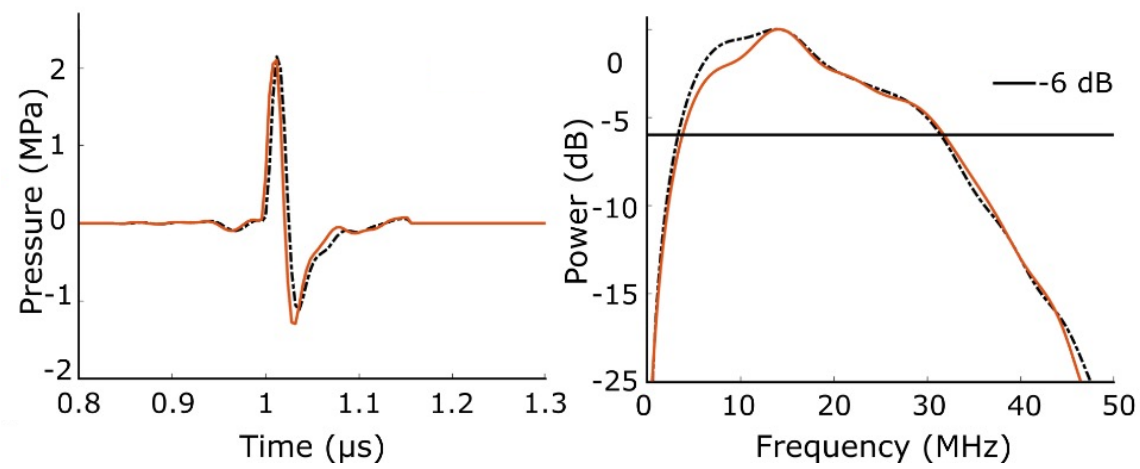


[6] LITT monitoring



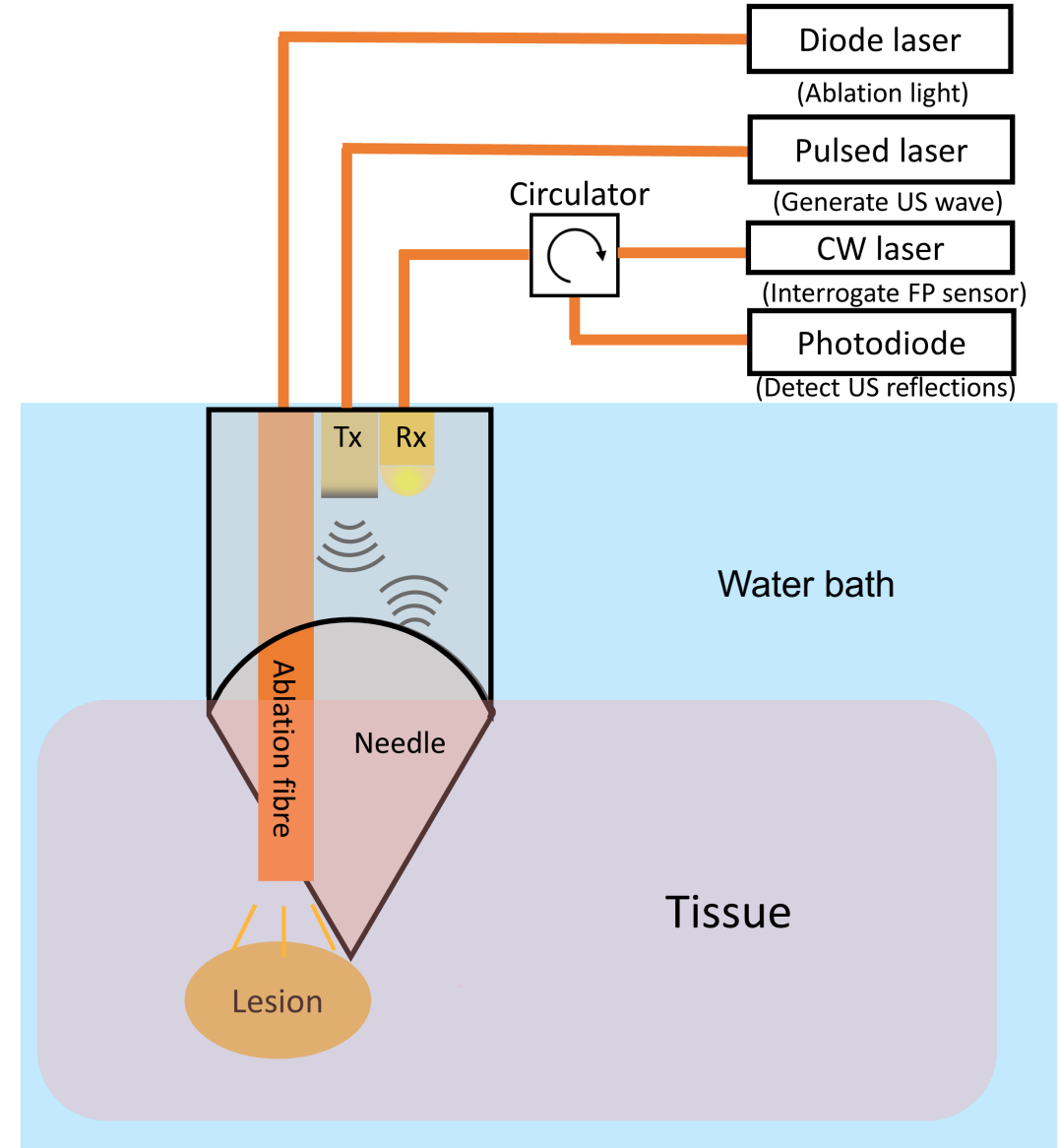
The Device

- Optical ultrasound transmitter: 200 μm core, **Candle soot nanoparticle-PDMS** coating:
 - Peak-to-peak Pressure @ 1.5 mm: **3.2 MPa**
 - Bandwidth @ 1.5 mm: **30 MHz**
- Receiver: plano-concave micro-resonator on SMF-28
- Ablation fibre: 400 μm core
- **Total Diameter: < 1 mm**
- Housing: medical needle with 2.75 mm OD



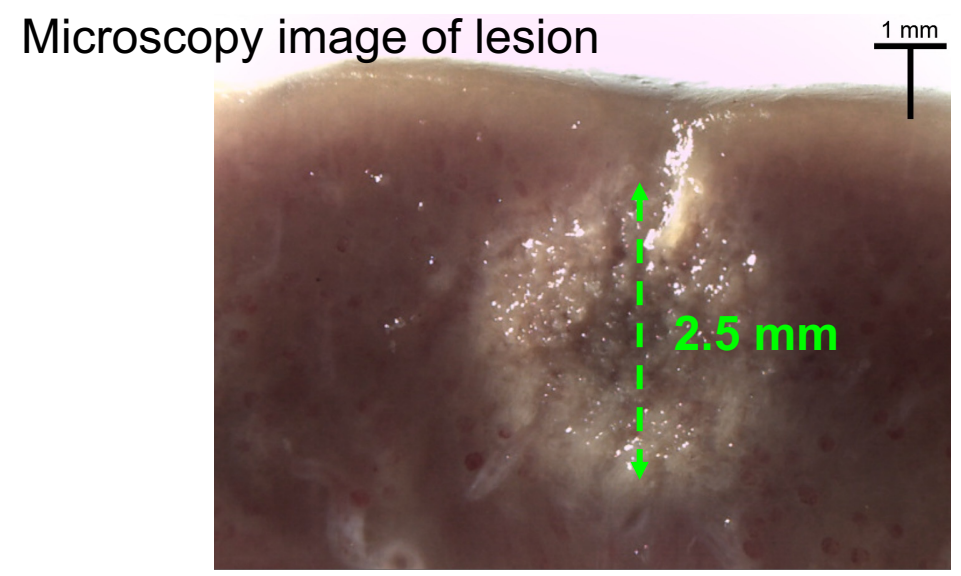
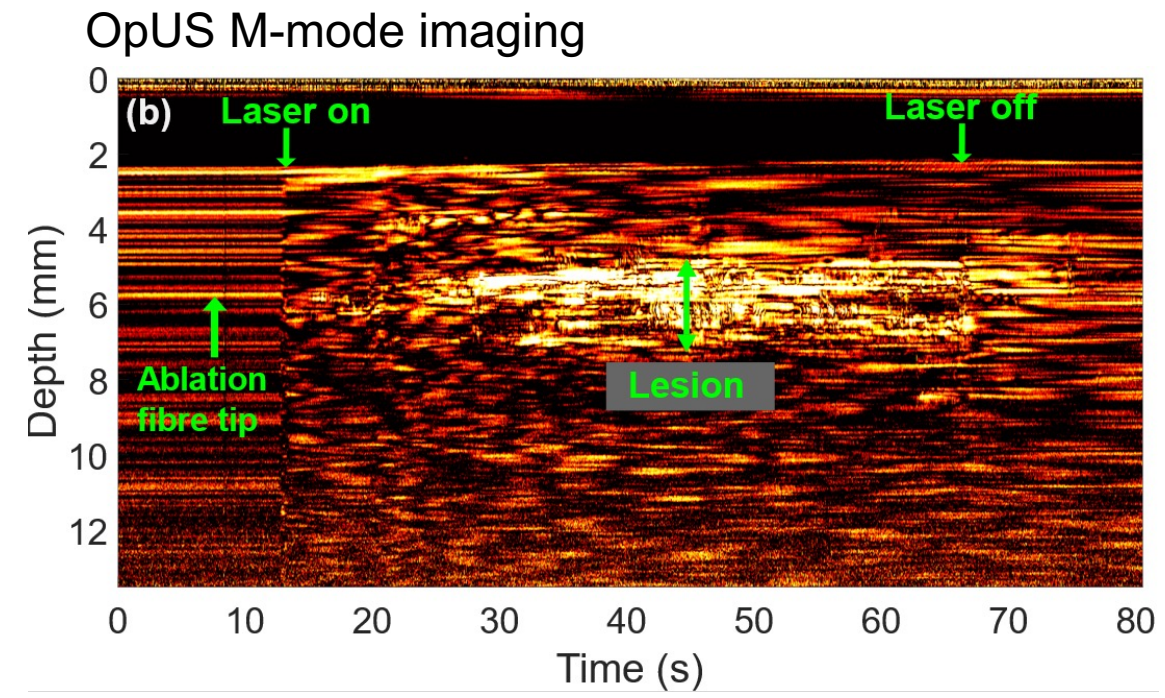
Imaging and ablation Setup

- Ultrasound generation: pulsed laser (2 ns, 1064 nm)
- Micro-resonator interrogation: Continuous wave laser (1500-1600 nm)
- Ablation light: Diode laser (808 nm, 3 W, 60 s)
- Ablation was performed whilst OpUS imaging to track lesion formation



Results

- Visualisation of the tissue throughout the procedure.
- Lesion grew bidirectional from the optical fibre tip in the vertical dimension
- Consistency of lesion depth measurement (2.5 mm) between OpUS and microscopy

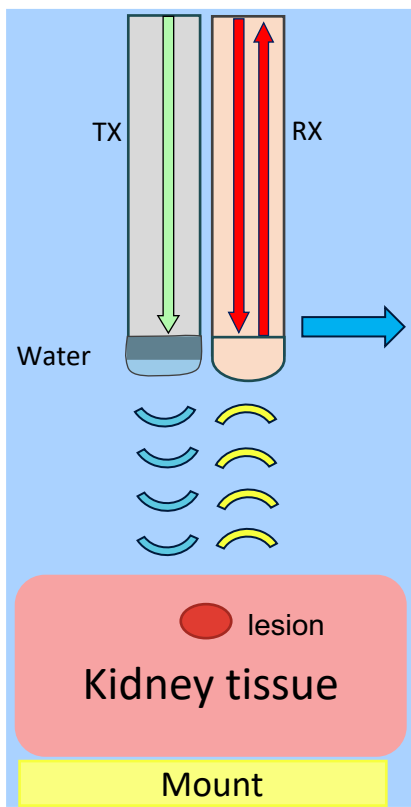


Results

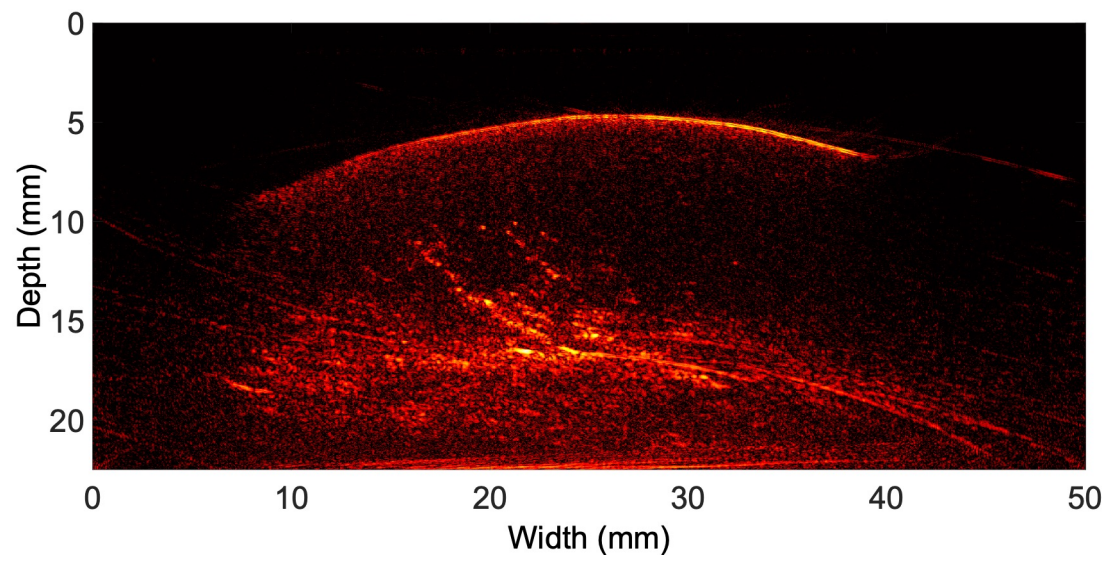
OpUS B-mode Imaging (pre- and post-ablation)

- Imaging depth > 15 mm
- Visualisation of the anatomic structure within kidney
- The lesion exhibits high brightness on post-ablation scan

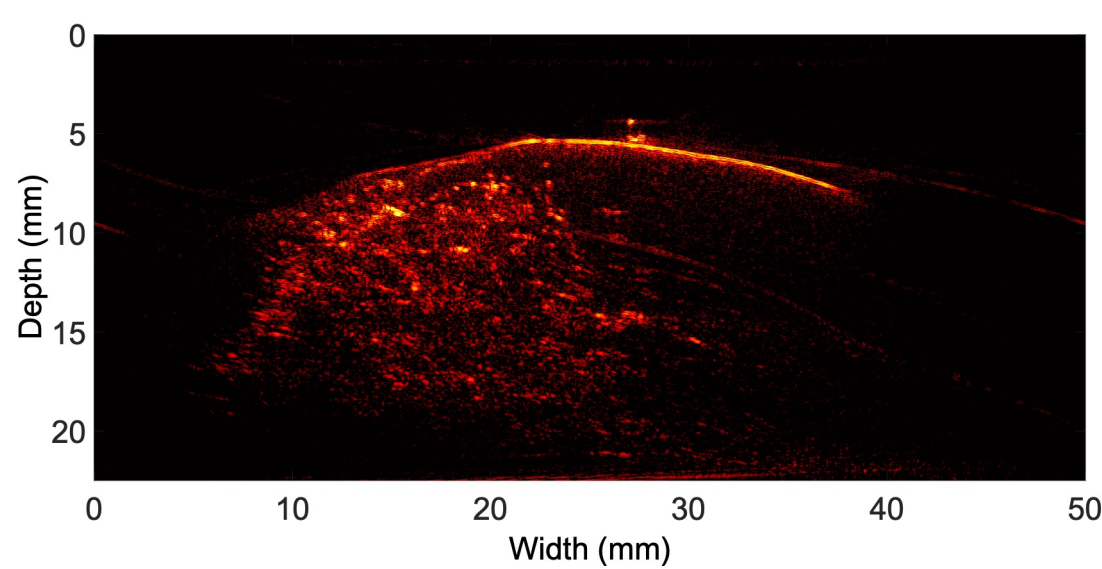
B-mode OpUS imaging



B-mode imaging before ablation

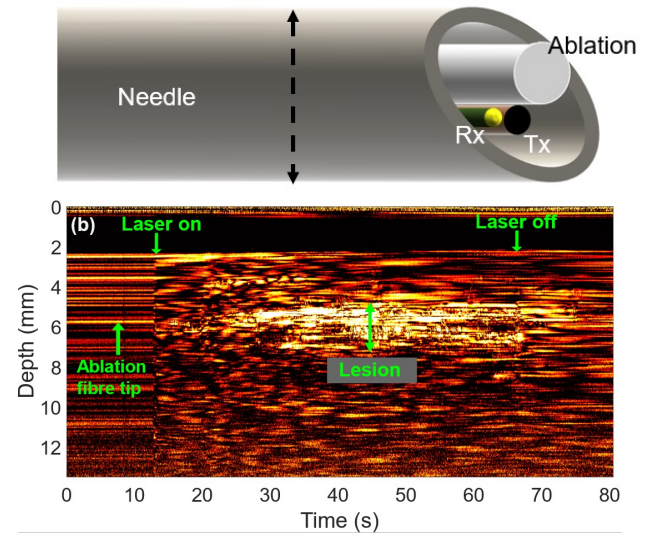
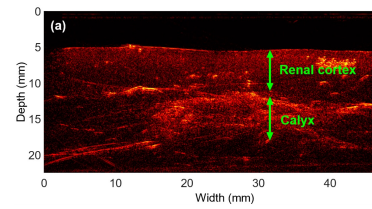


B-mode imaging after ablation



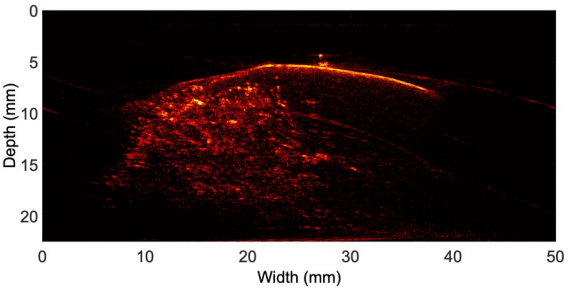
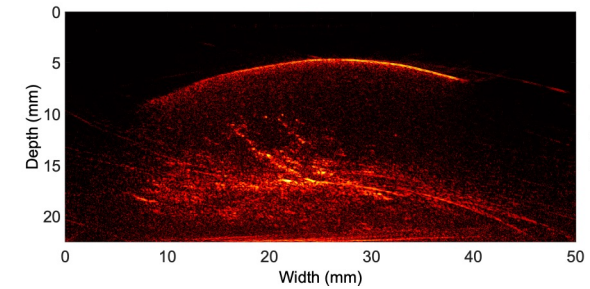
Conclusions

- Miniaturised device for minimally invasive procedures
- Optical ultrasound imaging for LITT monitoring
- Real-time information of lesion formation



Next step

- Comprehensive study
- Accuracy validation- Comparison between OpUS and microscopic measurement (statistical study)
- After *ex vivo* - development of device for *in vivo*



Acknowledgements

People

- Dr. Richard Colchester and Prof. Adrien Desjardins @ UCL
- Semyon Bodian, Dr. Sacha Noimark, India Lewis-Thompson @UCL
- Dr. Callum Little (Hammersmith Hospital, UK)
- Prof. Paul Beard, Dr. Edward Zhang, Dr. Sunish Mathews @ UCL
- Interventional Devices Lab @ UCL

Financial Support

- Royal Academy of Engineering
- Wellcome Trust & EPSRC (WEISS UCL)

Contact: shaoyan.zhang.20@ucl.ac.uk
richard.colchester@ucl.ac.uk

Website: <https://www.interventionaldevices.org/>



Royal Academy
of Engineering



wellcome
EPSRC centre
interventional+
surgical sciences

Interventional Devices Lab
@ UCL

Thank you!

Any questions?