Ultrafast Laser Microwelding of Dissimilar Materials at Oxford Lasers: Challenges and opportunities

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Acknowledgements

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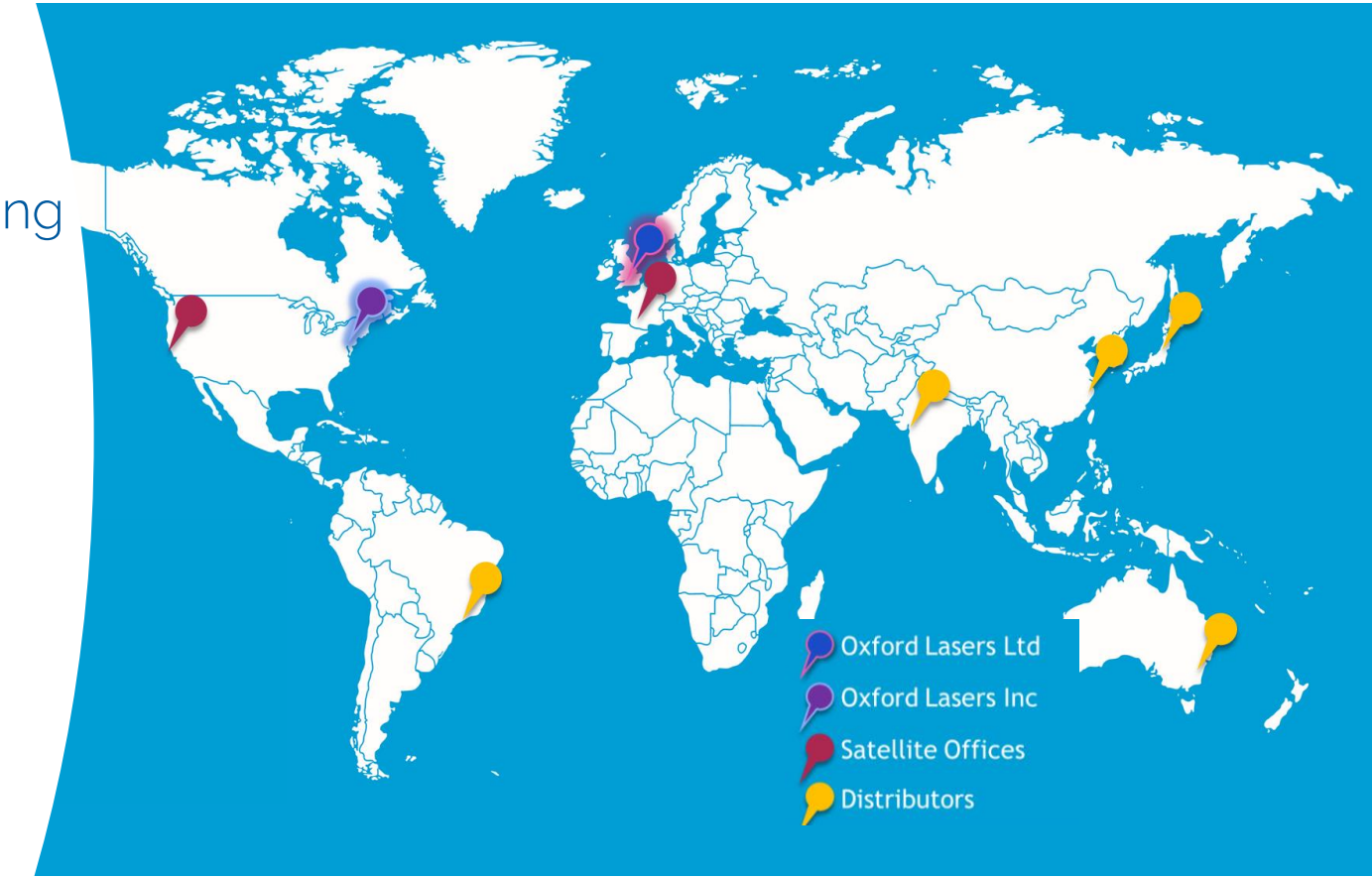
- Special thanks to Prof. Duncan Hand's group at Heriot-Watt University

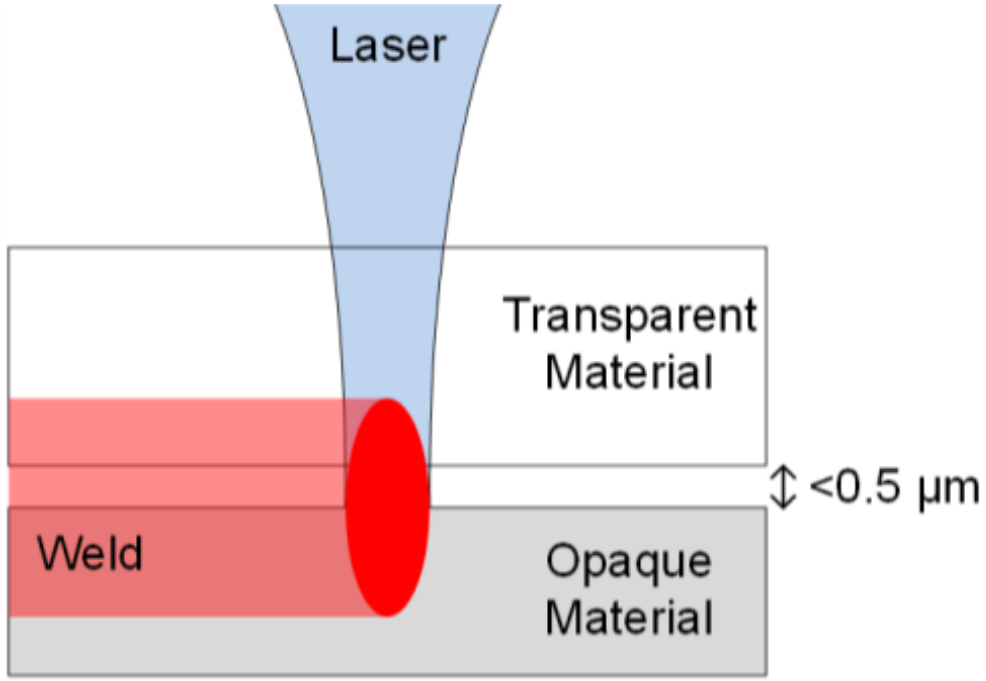
Oxford Lasers Group: Who we are

- Laser Systems Integrator
- Private SME, spinout U.Oxford (1977)
- Laser Micromachining & High-Speed Imaging **Products** and **Subcontract Services**
- Didcot, Oxfordshire (UK), Boston (USA)
- Semicon, Microelectronics, Aerospace, Pharma/Biomedical, Quantum Tech, Agrochemical, RTOs
- Highly skilled team (>30% postgrad/PhD)
- Growth via continuous innovation (27 Innovation programmes >10years)

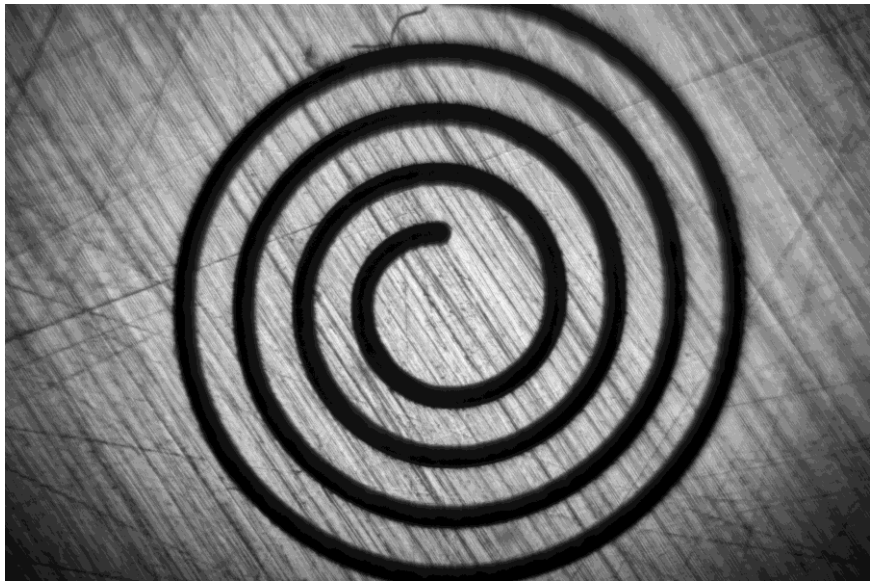


What is Laser Microwelding?

1. The laser is focused near the interface, going through the transparent material
   - **Ultrafast laser – better control** of melting/welding, non-linear absorption in glass



2. We translate the beam across the desired toolpath: **Weld line less than 50microns**
   - Concentric circles, spirals, rectangles, etc…



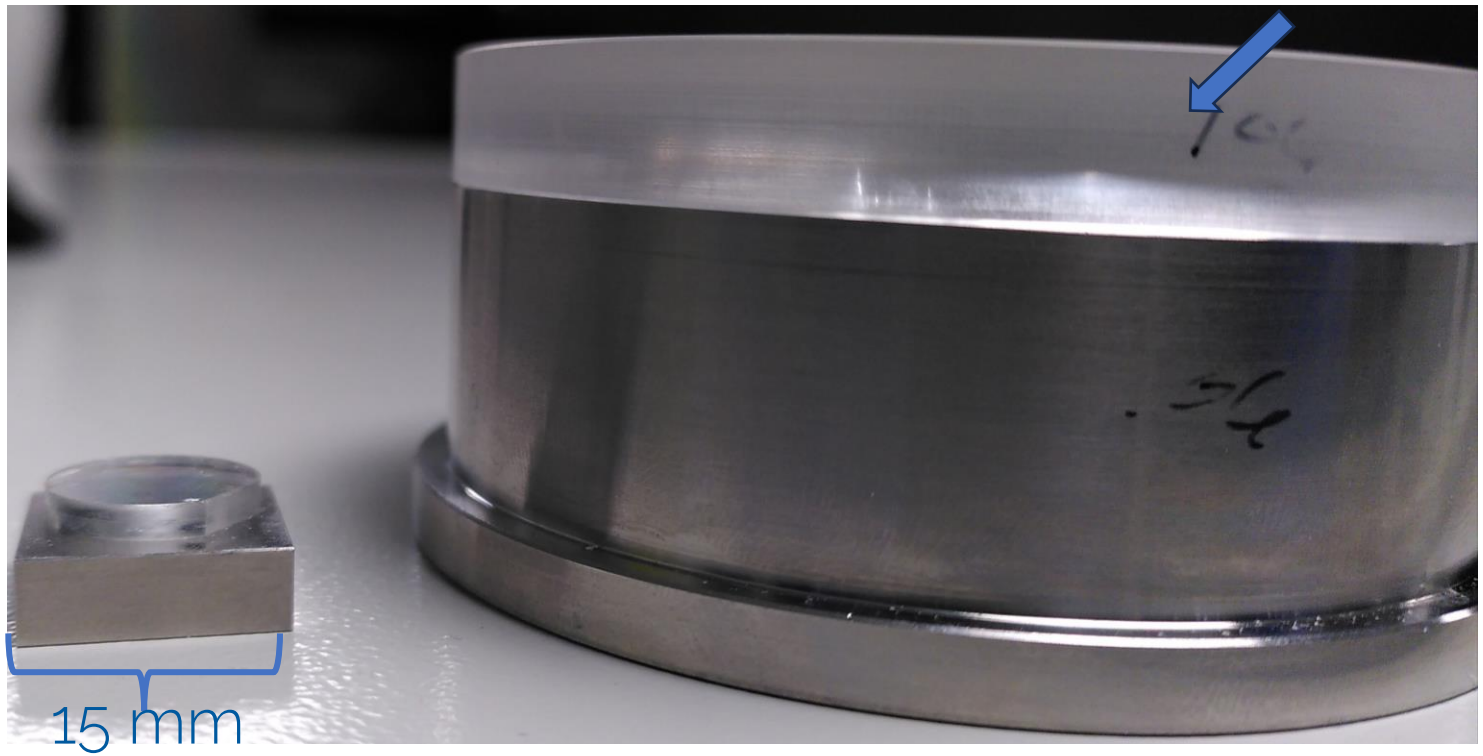
Why use Laser Microwelding?

- Alternative to adhesives but also other techniques such as diffusion bonding

- Typical advantage according to our customers:
  - No post-processing problems, i.e outgassing or volume change upon curing
  - High precision and speed
  - No dependency on human skill
  - Cost

Performance

- Proven process
  - Robust – broad range laser parameters.
  - **Varied sized (e.g. glass thickness from 0.5 mm to 20 mm),**
  - **Varied material combinations (more later)**
  - Through optical coatings

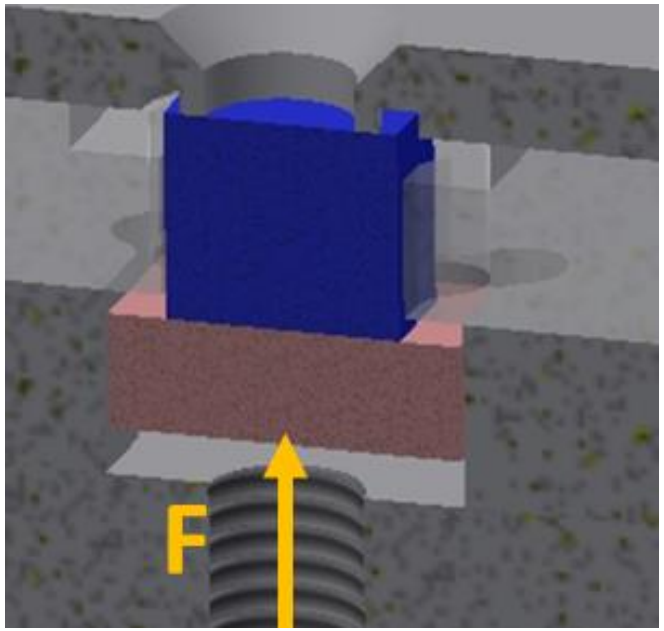


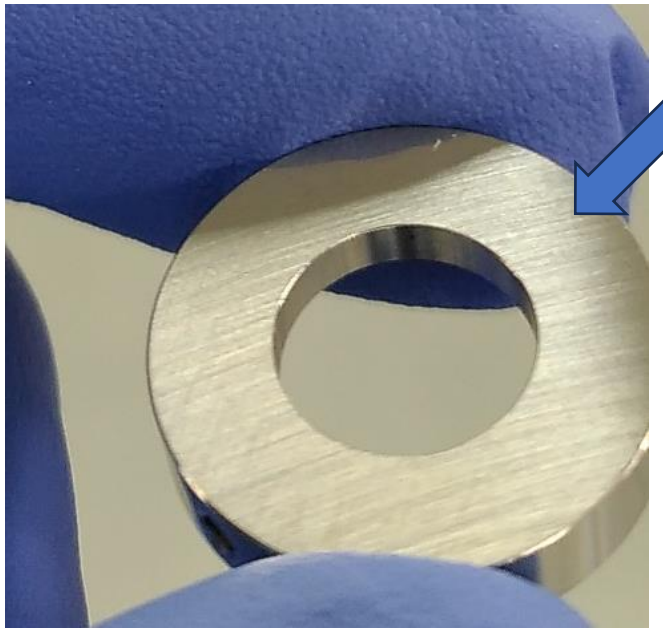
Laser Microwelding

Challenges

Surface quality

- Interface gap must be on the order of 1 μm or below
  - Surface quality: Flat, with low surface roughness
  - Samples clamped in place





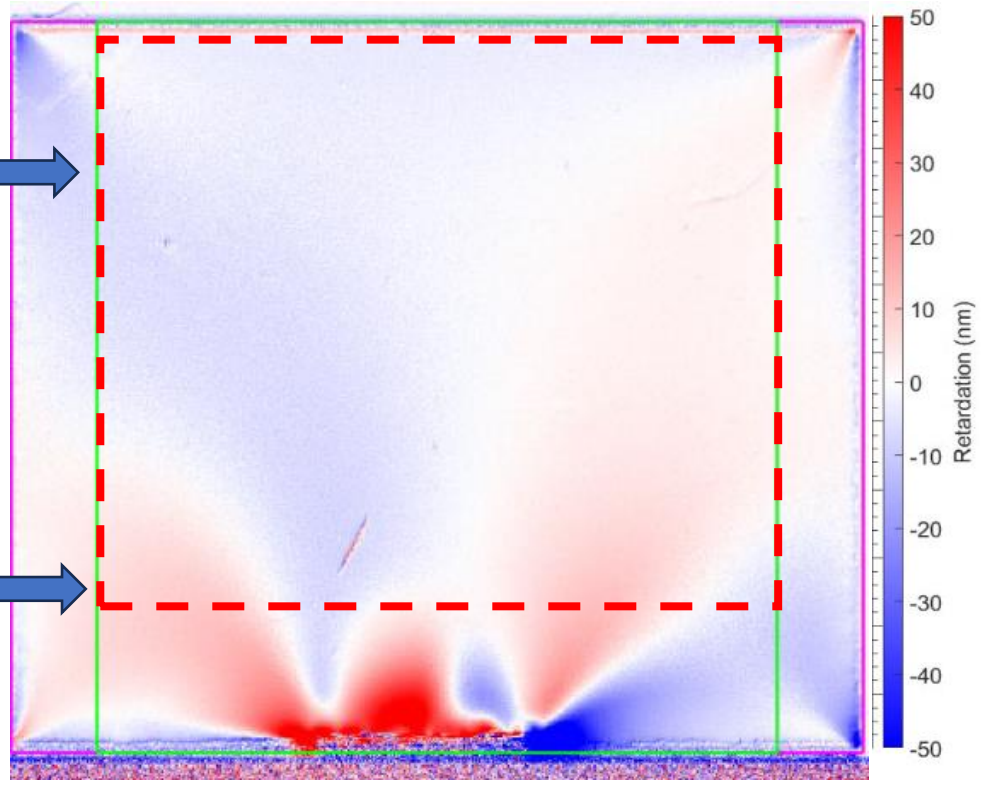
Typical surface quality

Stress-induced birefringence

- Caused by the rapid heating/cooling cycle during welding
- Can impact polarisation sensitive applications
- Tool to monitor stress in the weld

Reduced clear aperture

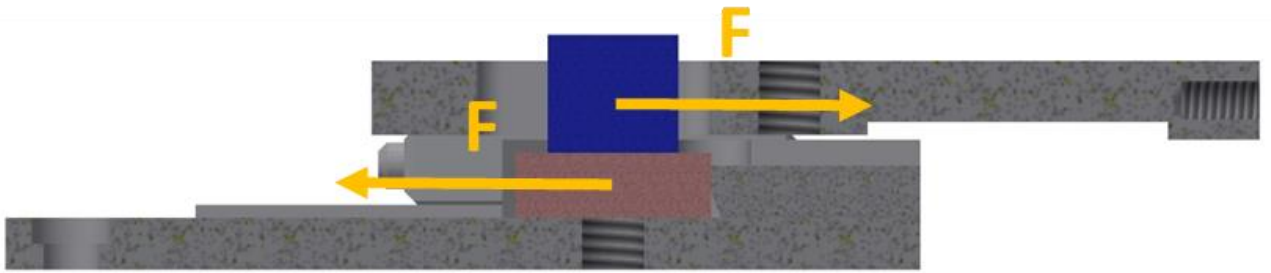
Stress from welding

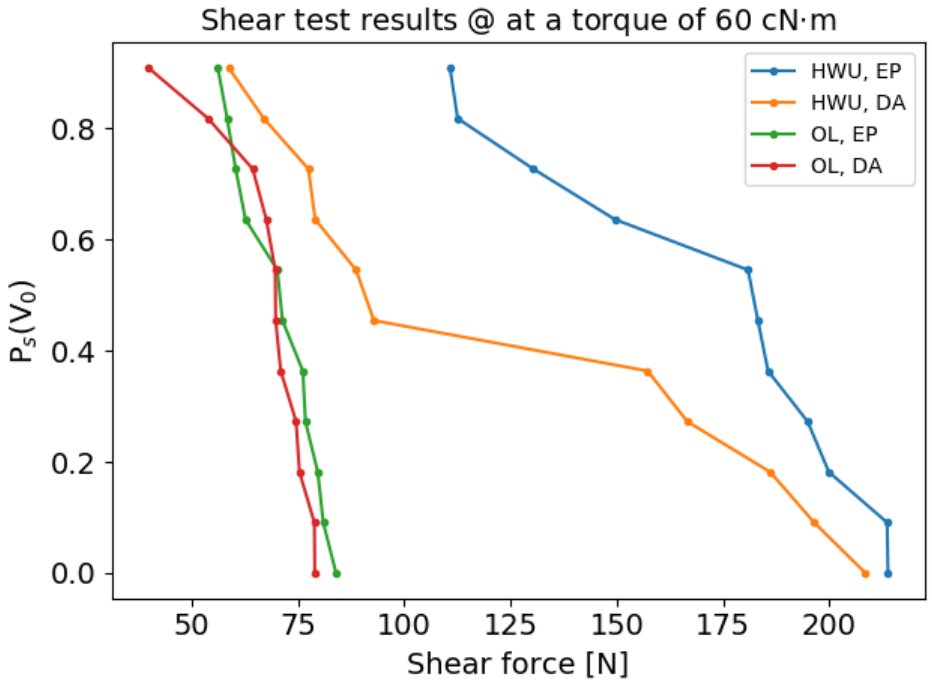


"Stress Induced Birefringence of Glass-to-Metal Ultrashort Pulse Welded Components" Hann, S et al, DP 7th Industrial Laser Applications Symposium 2021,

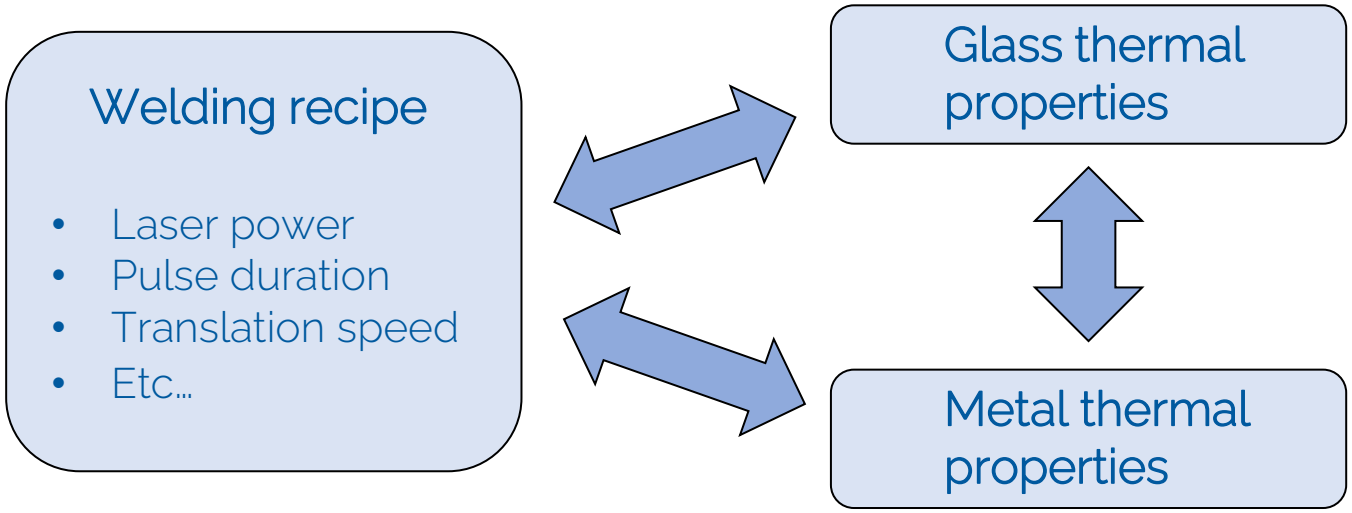
Testing

- More tests required than typical micro-machining
  - **Shear testing**
  - Birefringence
  - Thermal cycling
  - Vibration
  - Hermiticity





Predicting successful material combination



Best candidate?

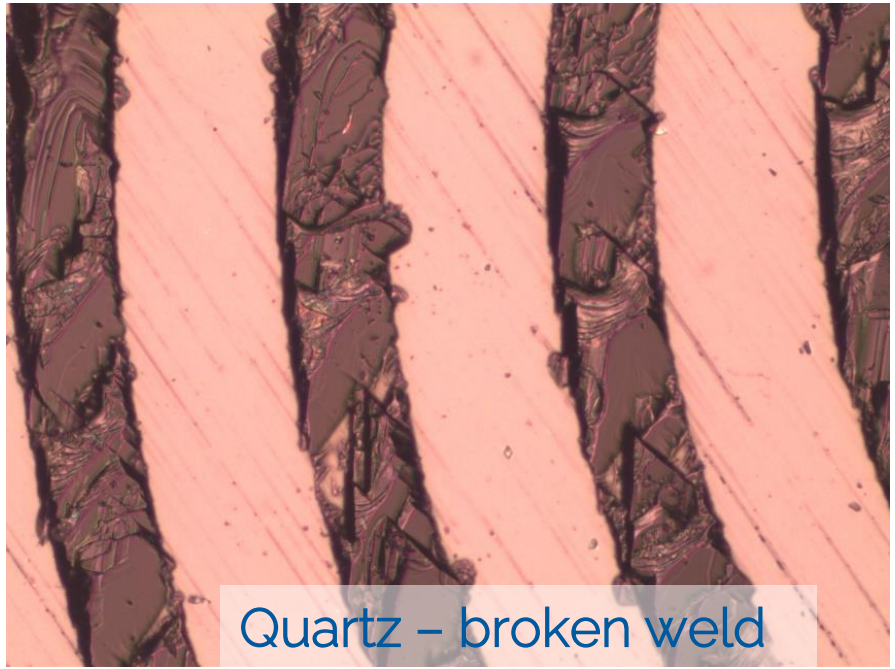
Thermal properties	CaF2	Quartz	Sapphire	Stainless steel*
Melting point	1423 ˚C	1650 ˚C	2040 ˚C	1450 ˚C
Thermal conductivity	10 W/m˚C	6 to 10 W/m˚C	40 W/m˚C	16 W/m˚C
Coefficient of thermal expansion	19 µm/m˚C	7.5 to 14 µm/m˚C	5 µm/m˚C	18 µm/m˚C

*BS en 10088 1.4301 (AISI 304)

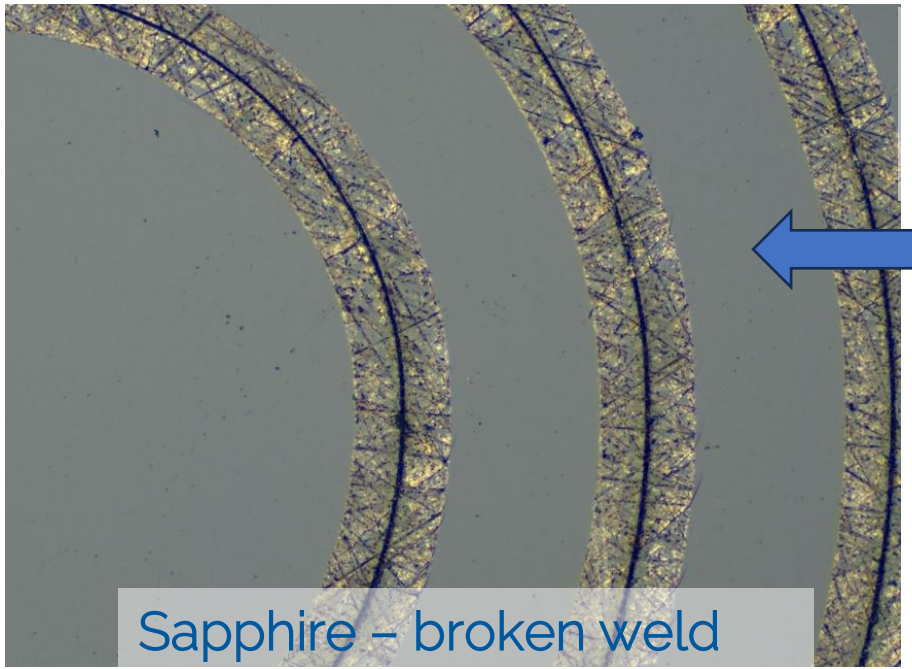
Material combination – Shear testing results

- Reference: **Quartz** – 60 to 100 N
- **CaF_2** – Difficulty making it work. Needed significant changes in recipe ~50 N.
- **Sapphire** > 200 N, different failure mechanism

Missing material
Weld broke
inside the quartz



Quartz – broken weld



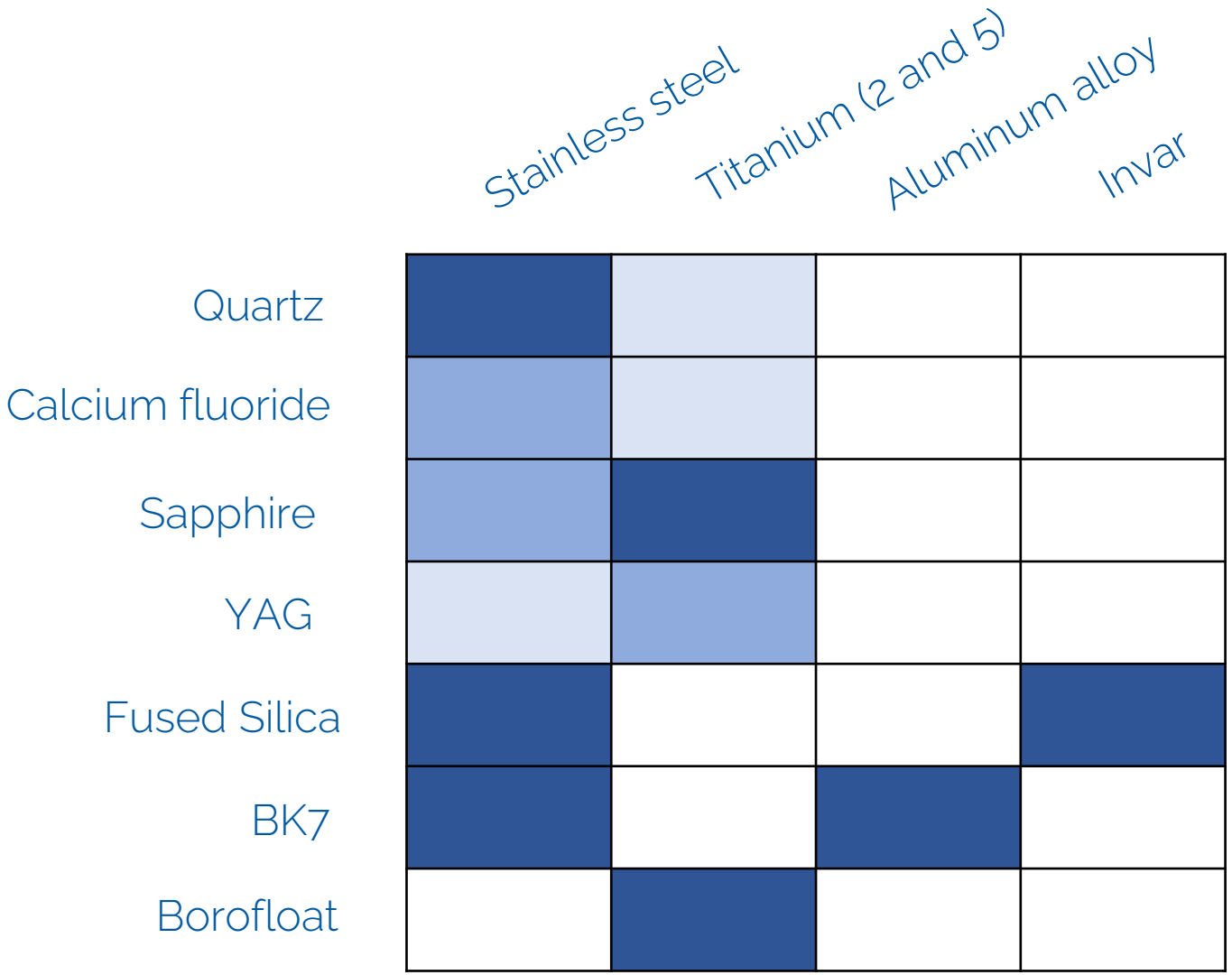
Sapphire – broken weld

Metal tracks
Weld broke
inside the metal

Laser microwelding

Opportunities

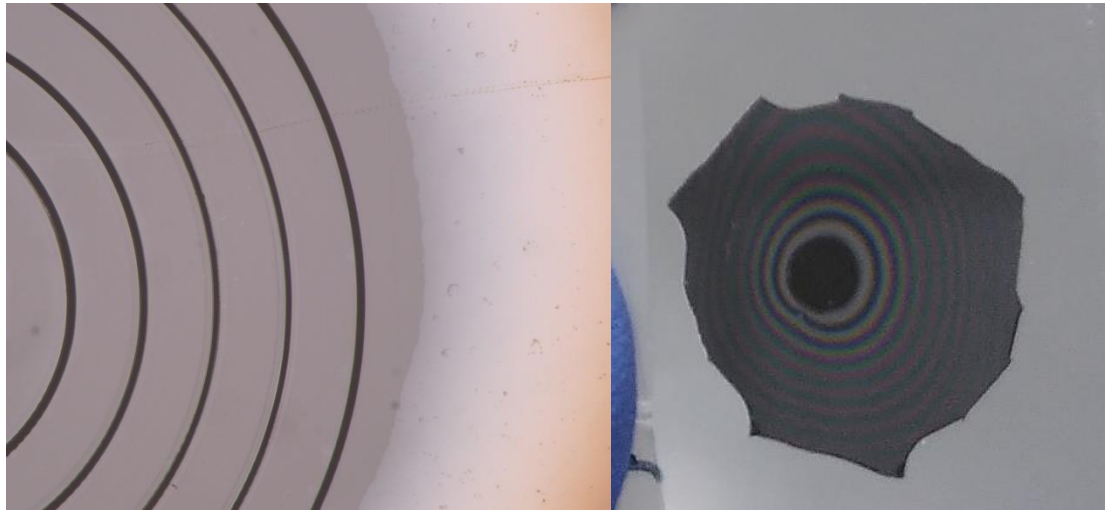
Material combination



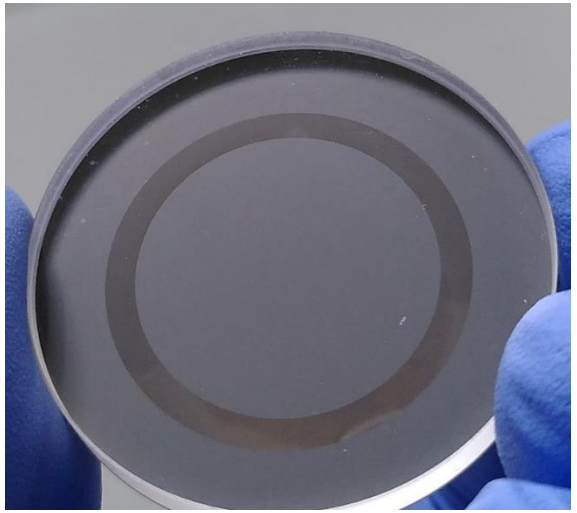
Other materials

- Glass to glass
- Recently welded Glass to Silicon and Silicon Nitride
  - Electronics applications
- Hermitic seal, precision positioning

Si

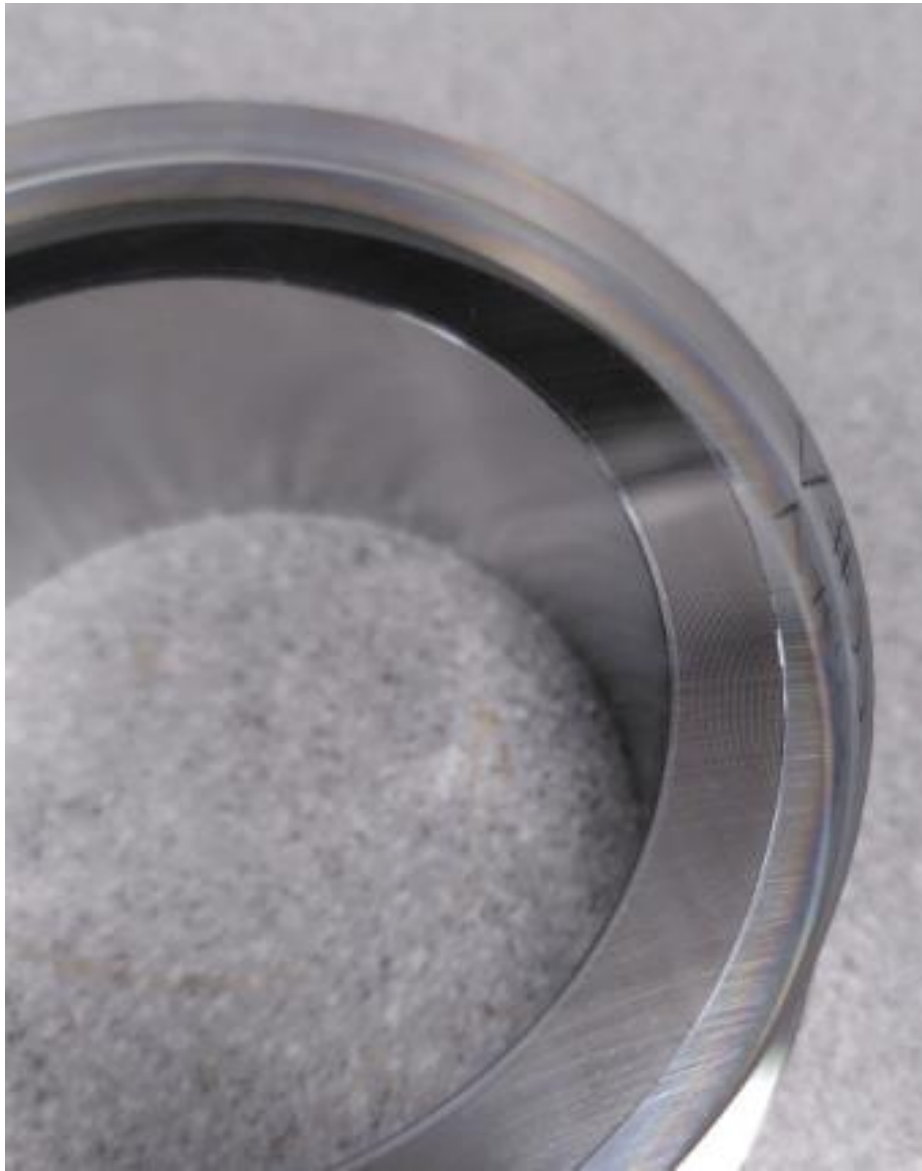


SiN



Welding for Hermetic Sealing

- Common requirement from customers
- First project: 75mm fused-silica window welded to stainless steel flange.
- Helium leak test: ~5×10^{-9} mbar/l·s
  - UHV compatible
- Worked with multiple customers on vacuum-related inquiries



New Innovate UK Project LINQED

- New grant-funded project centred around compact ion-trap system (UKRI 10100964)
  - https://gtr.ukri.org/projects?ref=10100964
- Other Partners:
  - University of Oxford (Dr Joseph Goodwin group)
  - Cold Quanta UK Ltd
- Laser microwelding for ion trap hermiticity

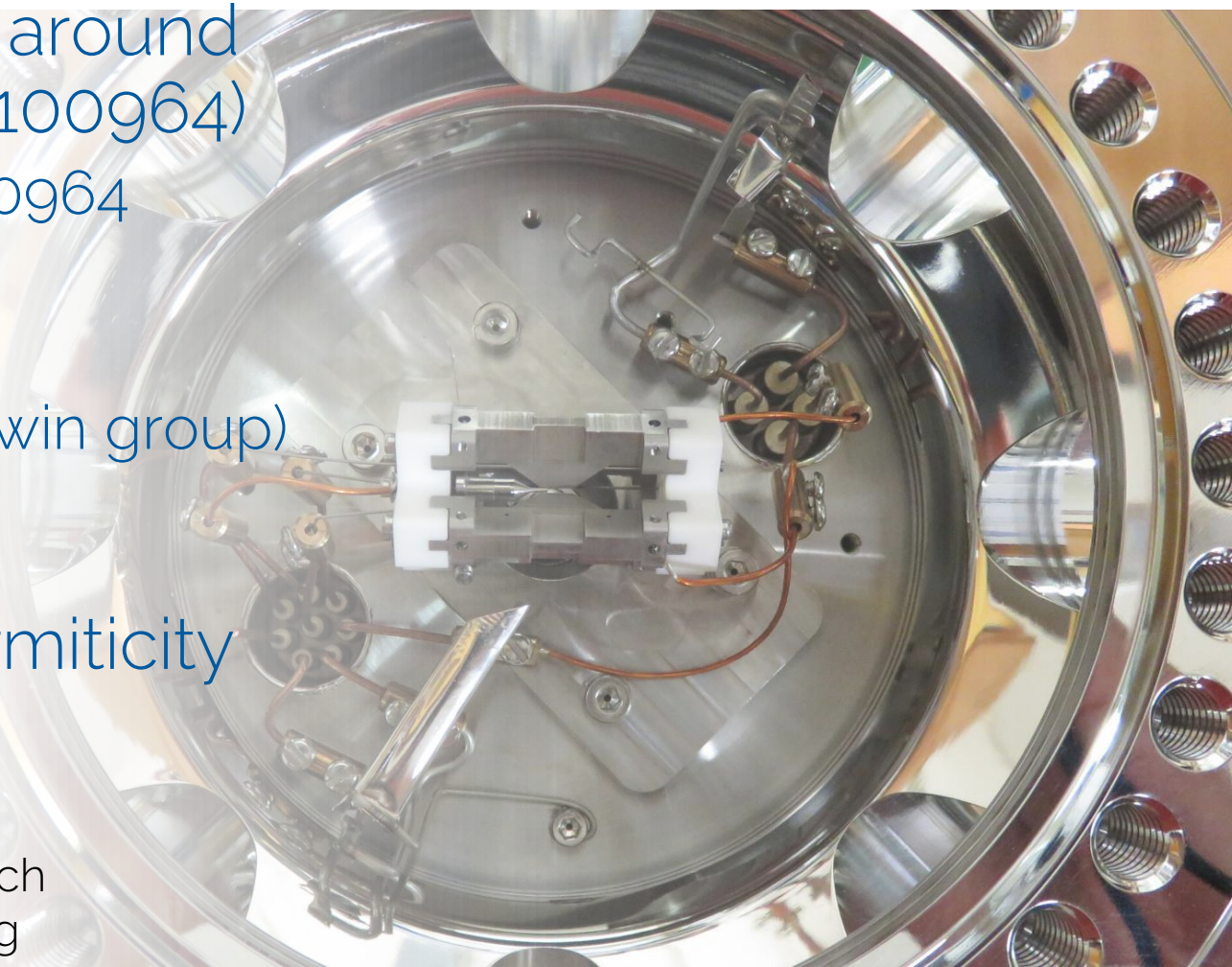


Image from https://www.physics.ox.ac.uk/research/group/ion-trap-quantum-computing

Conclusion and question

- Oxford Lasers has been working on laser microwelding for over 5 years.
- Ultrafast laser microwelding is addressing a real need and provides an effective solution.
- Different dissimilar material combinations are possible to weld with varying forms, sizes, thickness
- With our new project, LINQED, the future of ultrafast laser microwelding at Oxford Lasers looks bright!