MATERIALS THAT MATTER

# Niobium Welding

## CERN TTC

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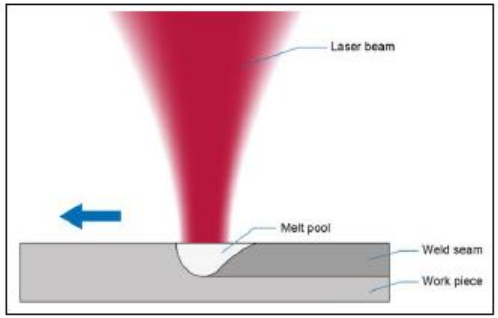
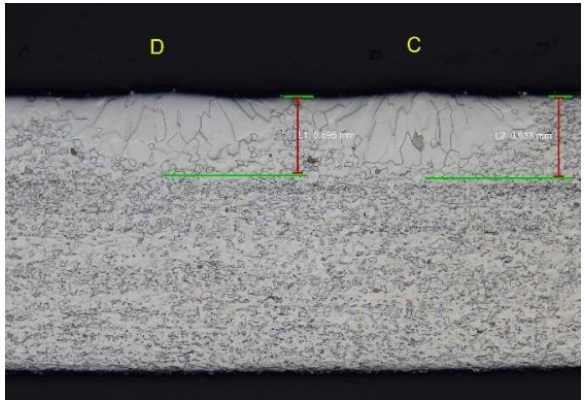
# Introduction

- **II-VI: Manufacturer of laser optics, photonics, and high-precision components**
  - 18 countries
  - 70 facilities
- **Niobium Laser Welding**
  - Primary Objectives
    - Maintain RRR
    - Increase Process Speed (2-4 meters/minute)
    - Reduce capital equipment cost
  - Secondary Objectives
    - Improve Repeatability/Automation
    - Remove tuning step
    - Reduce BCP/EP 90%

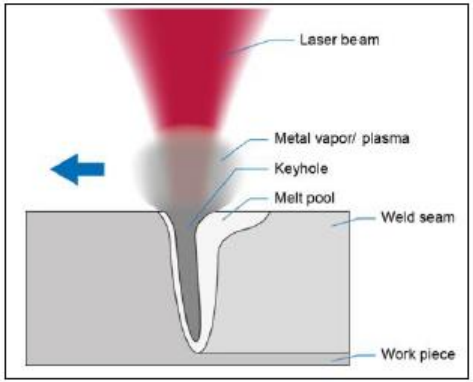
# Primary Laser Welding Methods

- **Conduction mode:**
  - **Melting** a given material
  - Depth of penetration controlled by energy and heat input




- **Keyhole mode:**
  - High energy density causes material **Vaporization**
  - Vapor pressure and heat generated control penetration



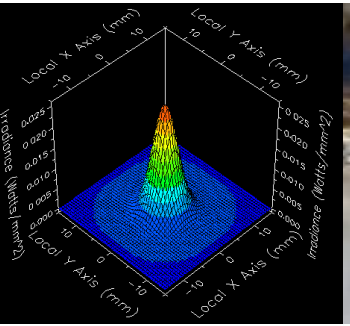

# Advanced Laser Welding Techniques

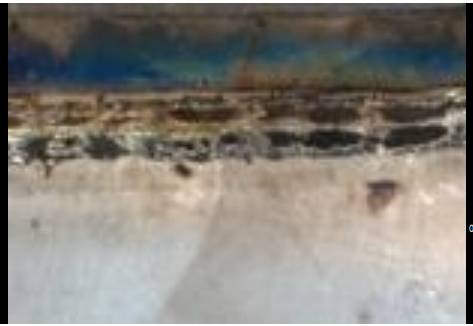
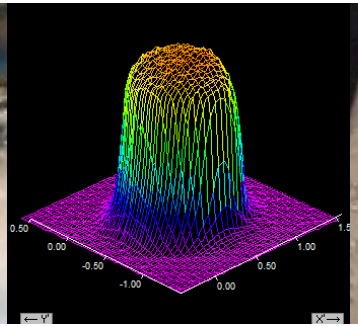
## “Classic” Parameters

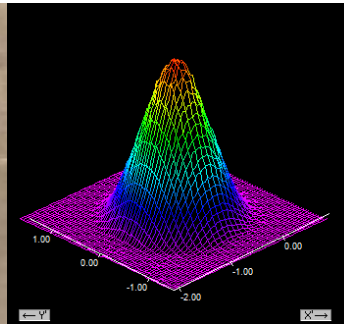
- Power Level
- Spot Size
- Travel Speed

## Critical Parameters

- Power Distribution (Beam Shape)
- Cover Gas
- Gas Flow

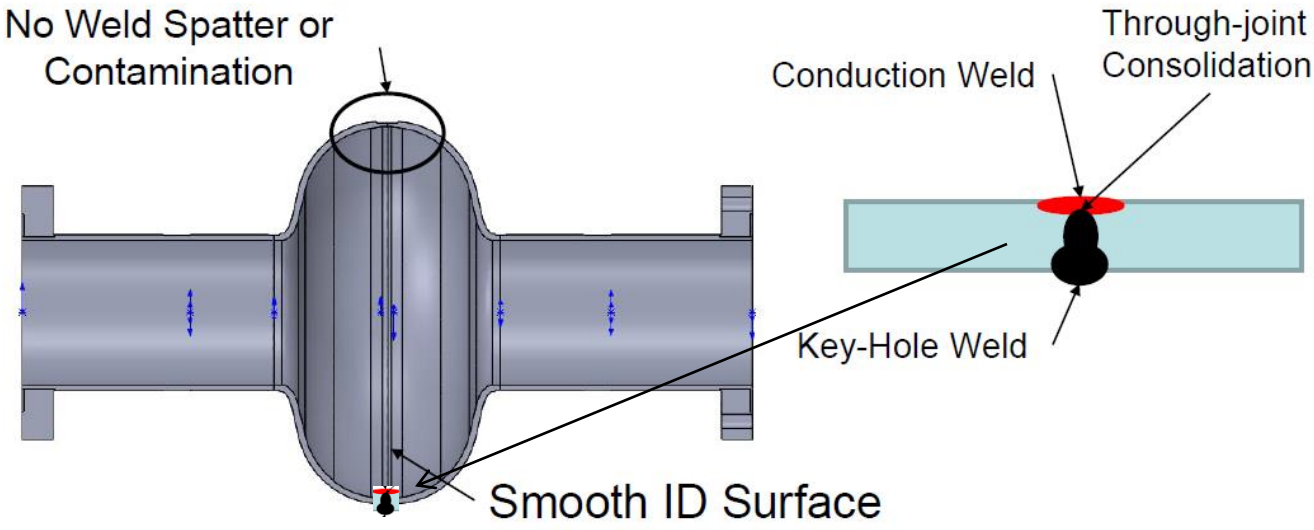




# Welding for Peak Performance

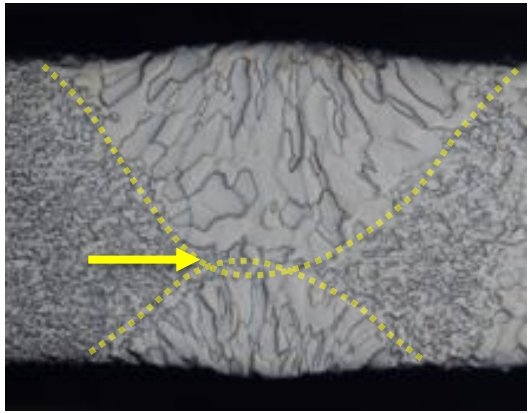
- In an effort to minimize the impact of weld on cavity performance, trials to eliminate spatter and reduce weld bead height were conducted
- A final combination of ‘inside-and-outside’ welds was decided



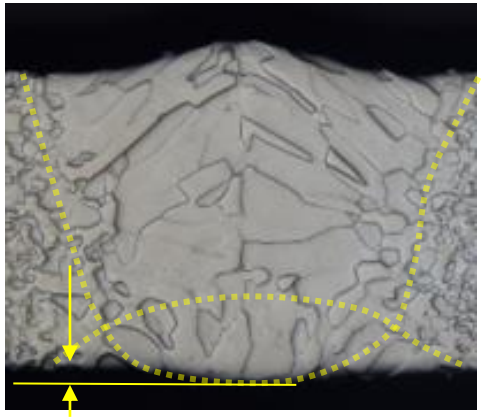
# Welding for Peak Performance

- **Create a complete weld with minimized surface roughness/profile**
- **No porosity allowable**
- **No impurities**

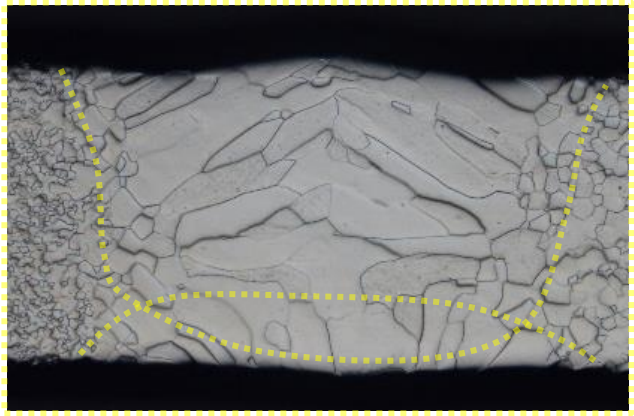
**Incomplete Consolidation**
Smooth ID Weld



Complete Consolidation
**Excessive ID Reinforcement**

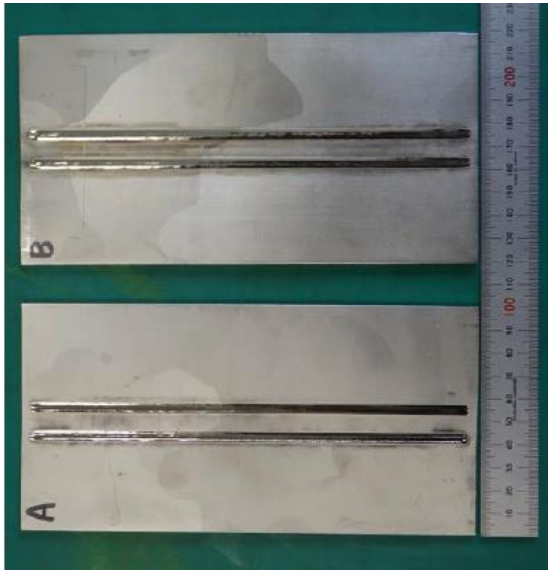


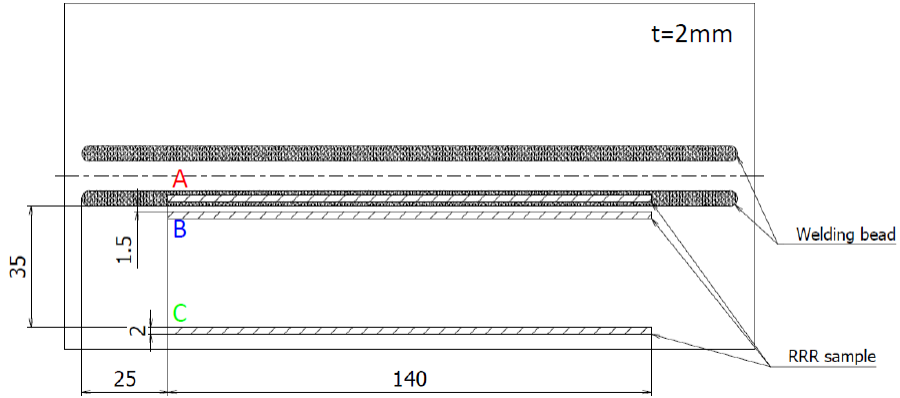
Complete Consolidation
Smooth ID Weld



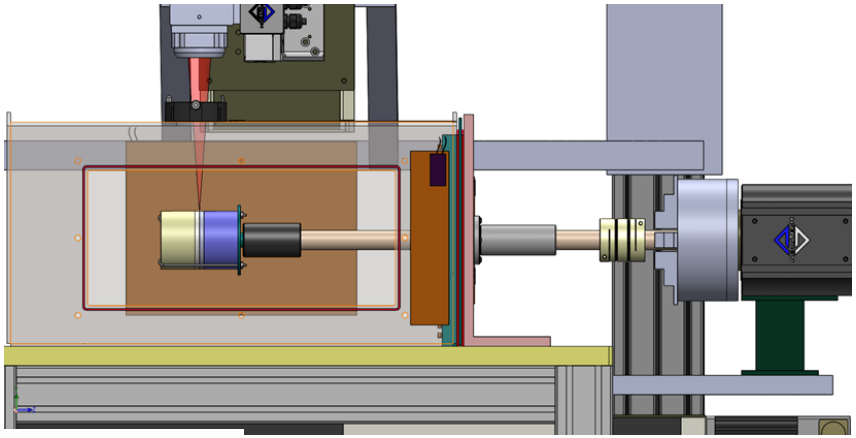
# Test Setup

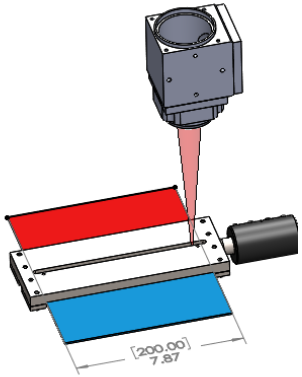
- **Samples were prepared in an argon atmosphere with welds on both sides of the material.**
  - CBMM 4th Melt Ingot
  - 2mm thick material
  - Two welds were done in parallel to simulate the thickness of an EBW bead (4 total welding passes/bead)
- **(KEK) RRR testing for samples**
  - Machine samples
    - Weld Bead (A)
    - HAZ (B)
    - Unaffected material (C)
  - Peel
  - Etch
  - RRR Test

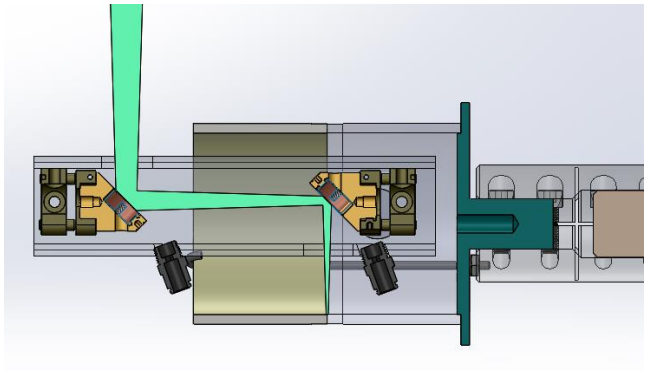


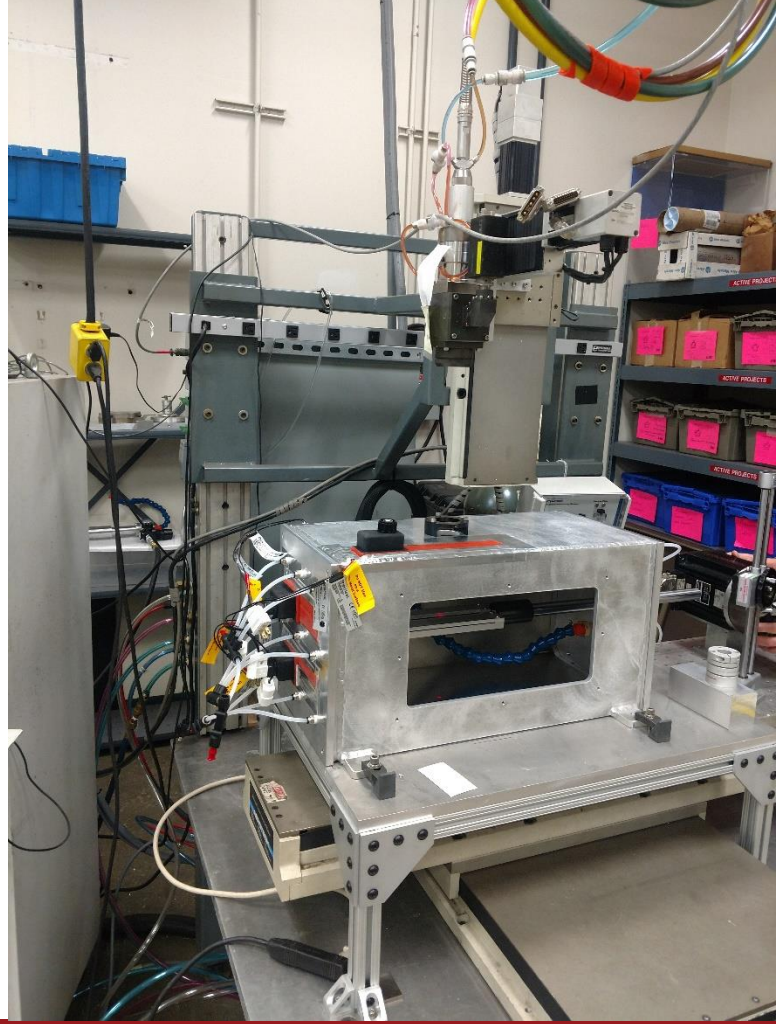



# Weld Setup





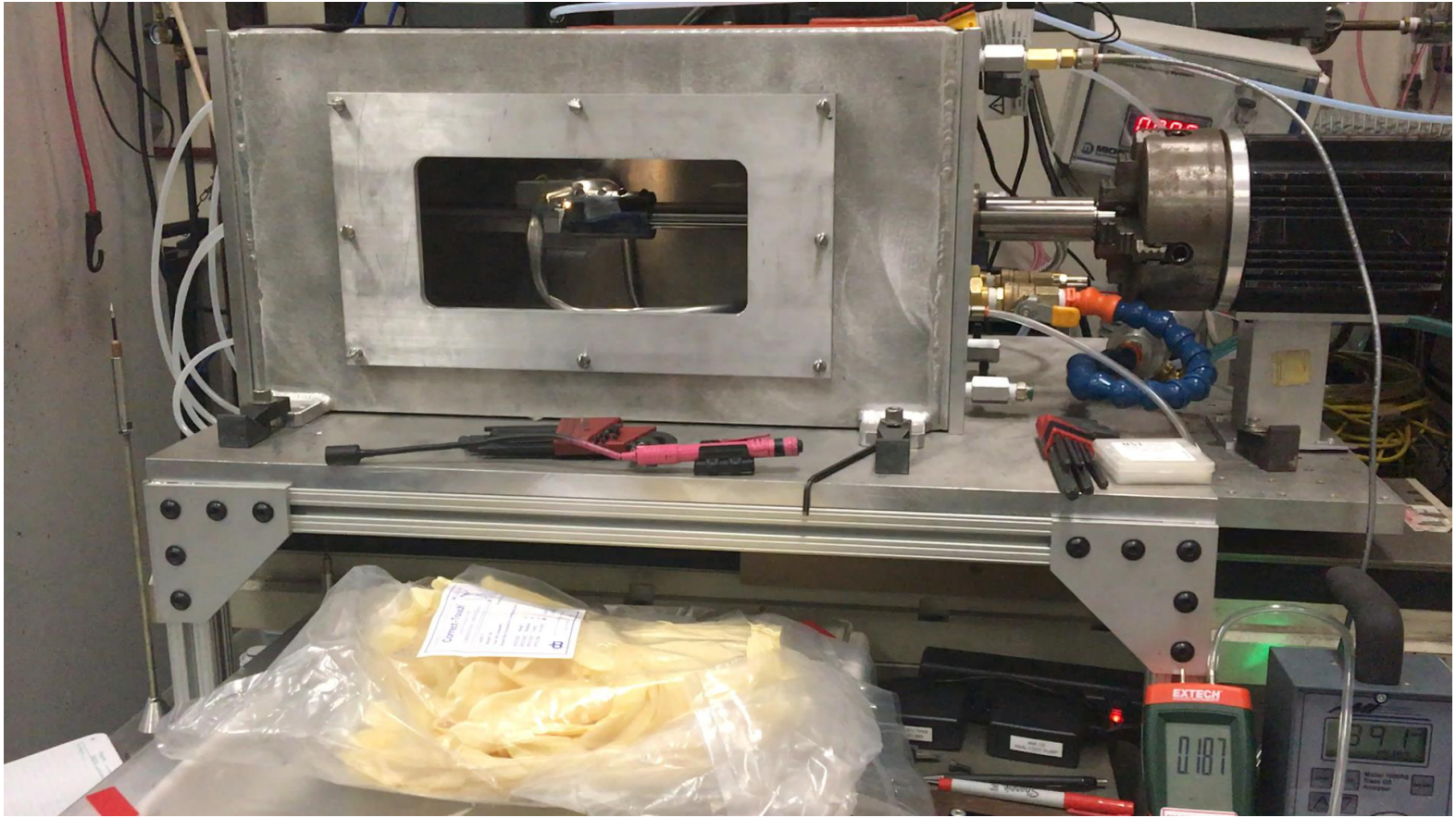





# Weld Prep

- Wire EDM 2.1mm slice from ingot
- Machine into 200mm x 100mm blank
- BCP 25 microns
- Clean room transfer
- Heat assisted argon purge

# Welding

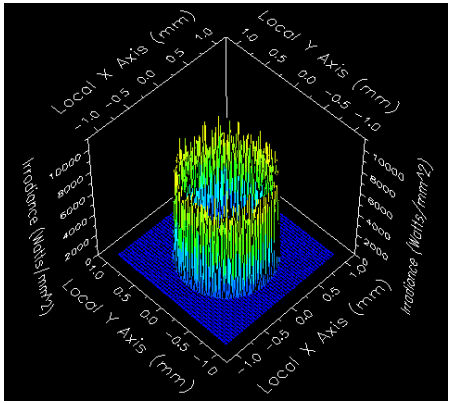


# Results

- **Low profile welds**
- **Consistent, repeatable process**
- **2⁺m/min weld speed**
- **RRR Testing underway**
  - Further work
    - Sheet B additional BCP
    - Anneal and repeat measurement
    - EBW on base sheet for comparison
- **Additional Experiments Possible**
  - High RRR Sheet
  - Tube-to-Tube
  - Mixed Materials
  - Beam Shaping
  - High Speed
  - Reduced Weld Width

| RRR Values (KEK Dec '19) | Sheet A (25 micron BCP) | Sheet B (5 micron BCP) |
|---|---|---|
| Base material 1 C | 71.4 | 71.4 |
| Base Material 2 C | 73.6 | 71.9 |
| HAZ B | 73.7 | 73.1 |
| Weld Bead A | 71.7 | 61.3 |

Preliminary





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