Diode Laser Assisted Friction Stir Welding of HY80 Steel

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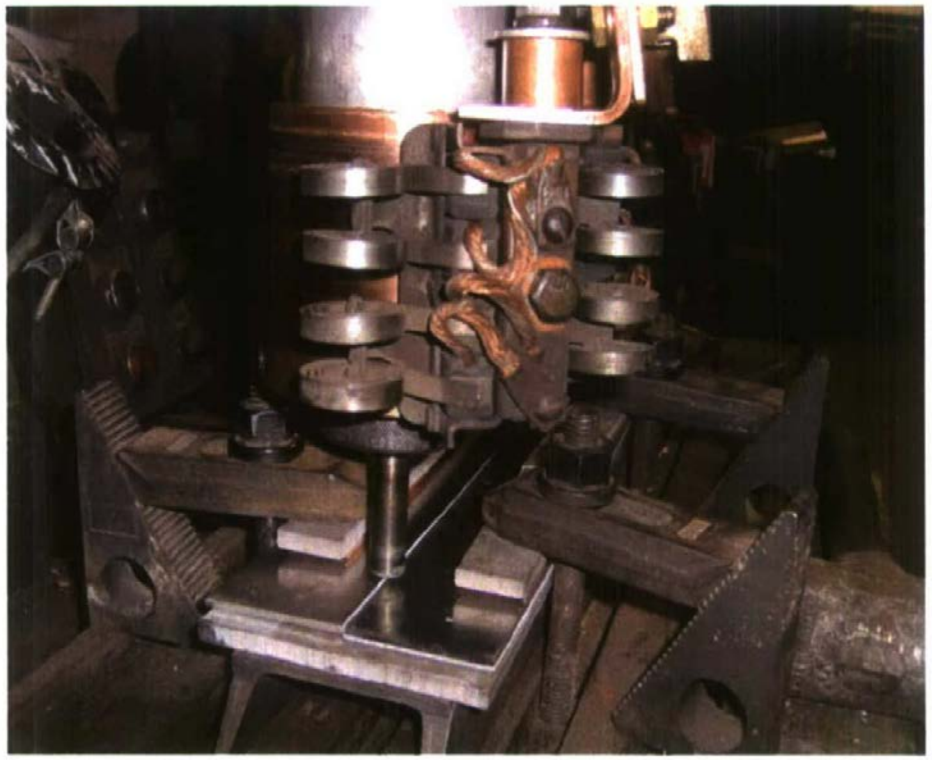
Hybrid Friction Stir Welding

In attempts to soften the workpiece prior to FSW, several hybrid FSW techniques have been proposed and/or attempted (none are production level operational):

Contact required
- Electrically Assisted, Conductive Assisted, Vibration Assisted

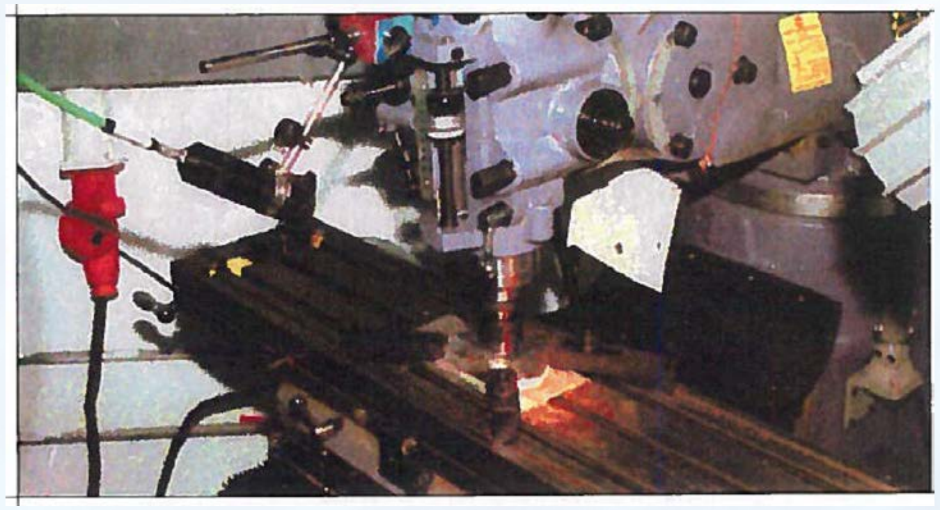
No-contact required
- Gas tungsten arc Assisted, Ultrasonic Assisted, High Frequency Induction Assisted, Laser Assisted

Laser Assisted Friciton Stir Welding (LAFSW)
- The earliest demonstration was in 2002. A total of 10 papers are readily available (accounting for only 5 different setups), but none have reached production level capability and all use complex (expensive) laser systems.

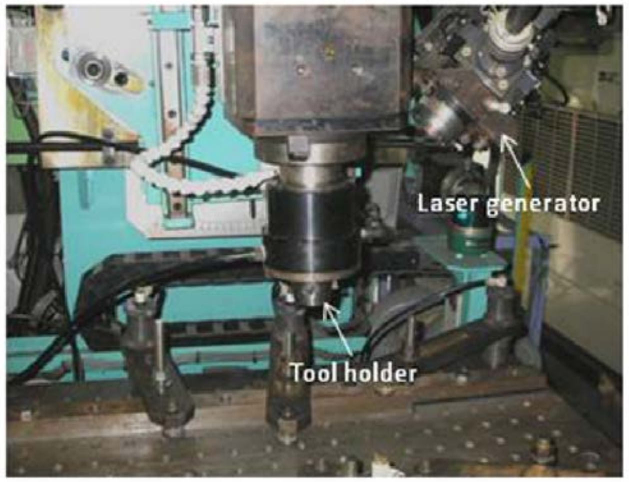


Electrically Assisted, Ferrando, 2005

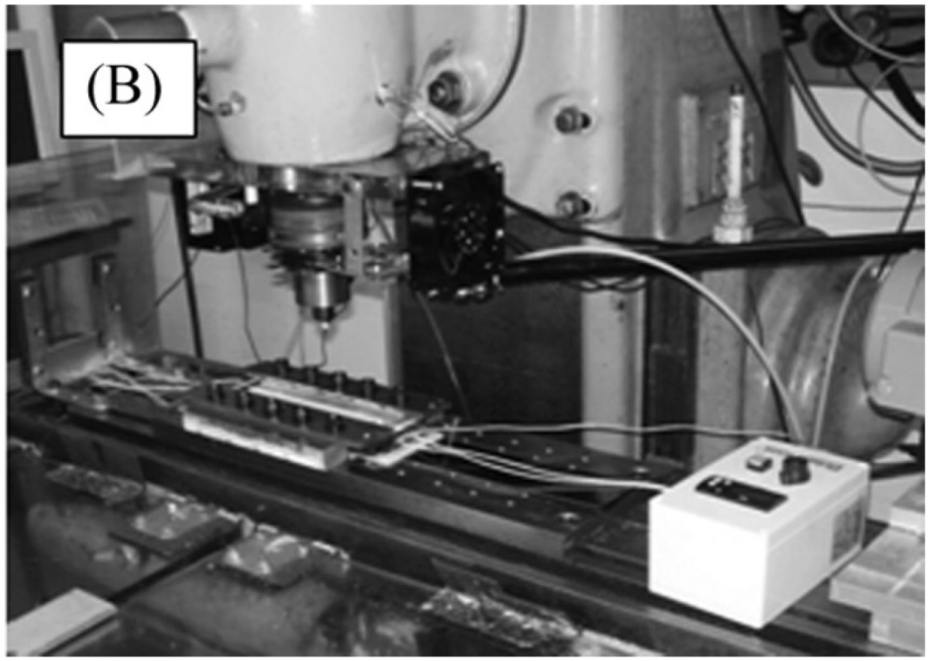
Contact methods will heat/affect the entire workpiece not just the weld area



LAFSW (YAG), Kohn, 2002



LAFSW (YAG), Sun, 2013

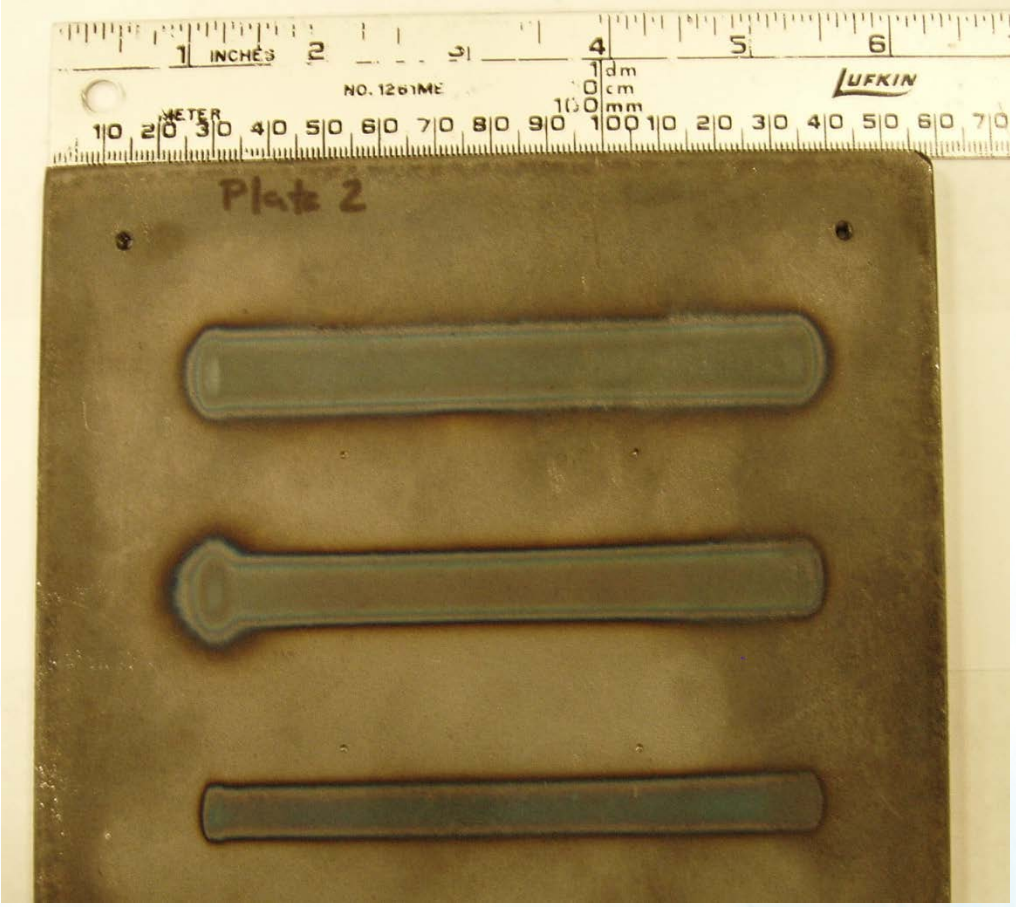


Conductive Assisted, Sinclair, 2010

Why Use Lasers?

There is a remarkable similarity in the weld path created by FSW and the heated area created by a laser or laser array. Others hybrid FSW methods do not confine the heat to the weld path nearly as well. This precision and controllability is significant advantage of LAFSW.

MA956 steel friction stir welded in similar LLNL research
(FSW done by MegaStir)



HY80 steel heated by diode laser array (at various currents, all <25% of array power capacity)

Why Use Diode Lasers (DLAFSW)?

Workpiece control

Diode laser preheating offers significantly greater precision and controllability of the heated area in the workpiece than other methods.

Cost

High Power Diode Laser Arrays (HPDL) are less expensive (2-5x less expensive) than conventional lasers systems.

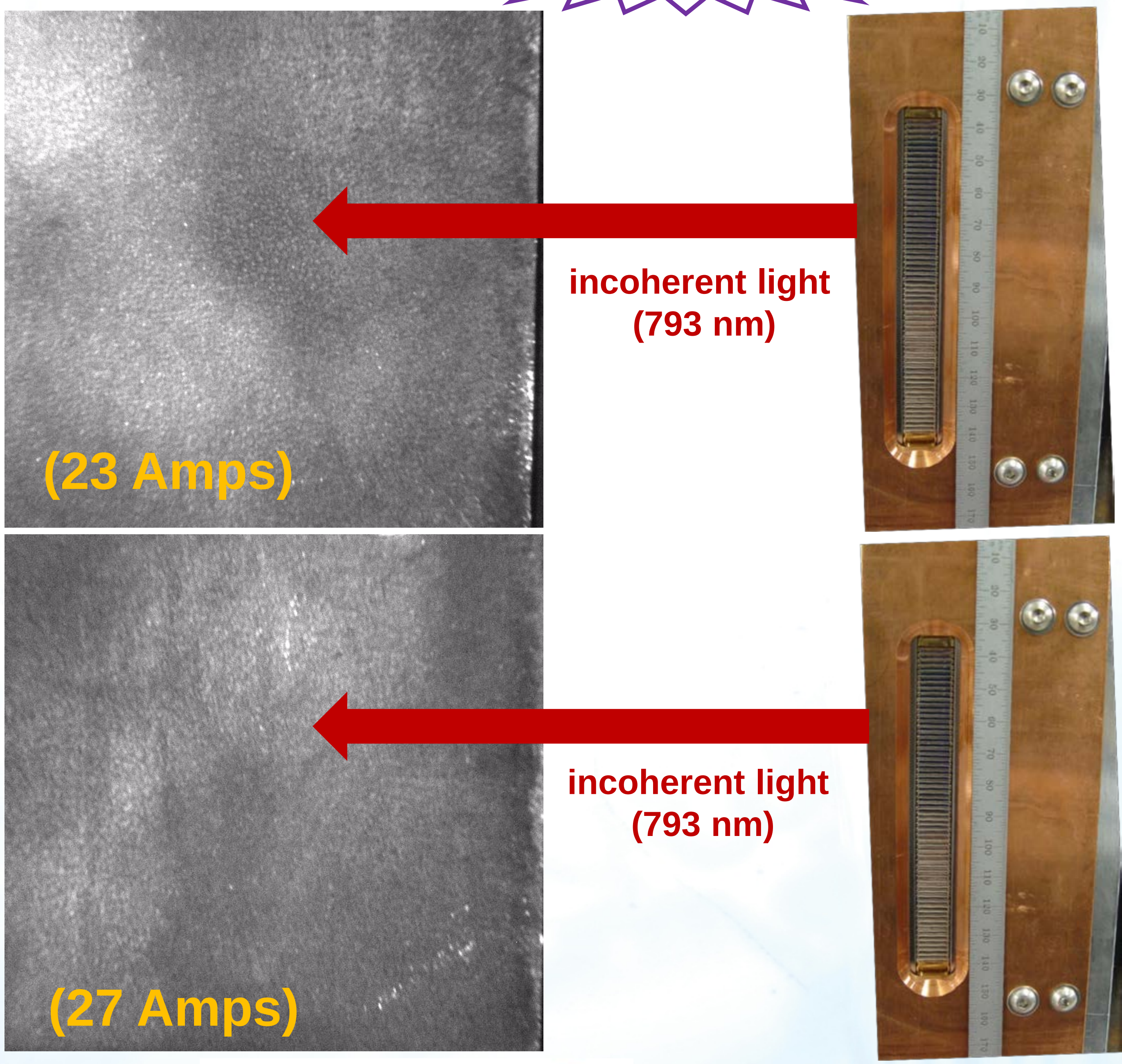
Safety

The light leaving the diode array is incoherent light as opposed to coherent light due to the multiple (60) lasers in the diode array.

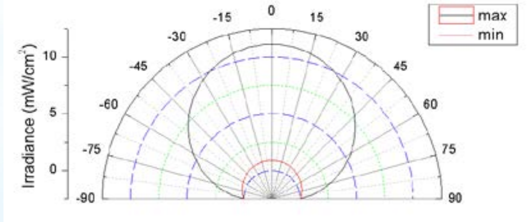
Scattered light is almost negligible.

The only PPE requirement is amber goggles.

scattered light
<10 mW/cm^2



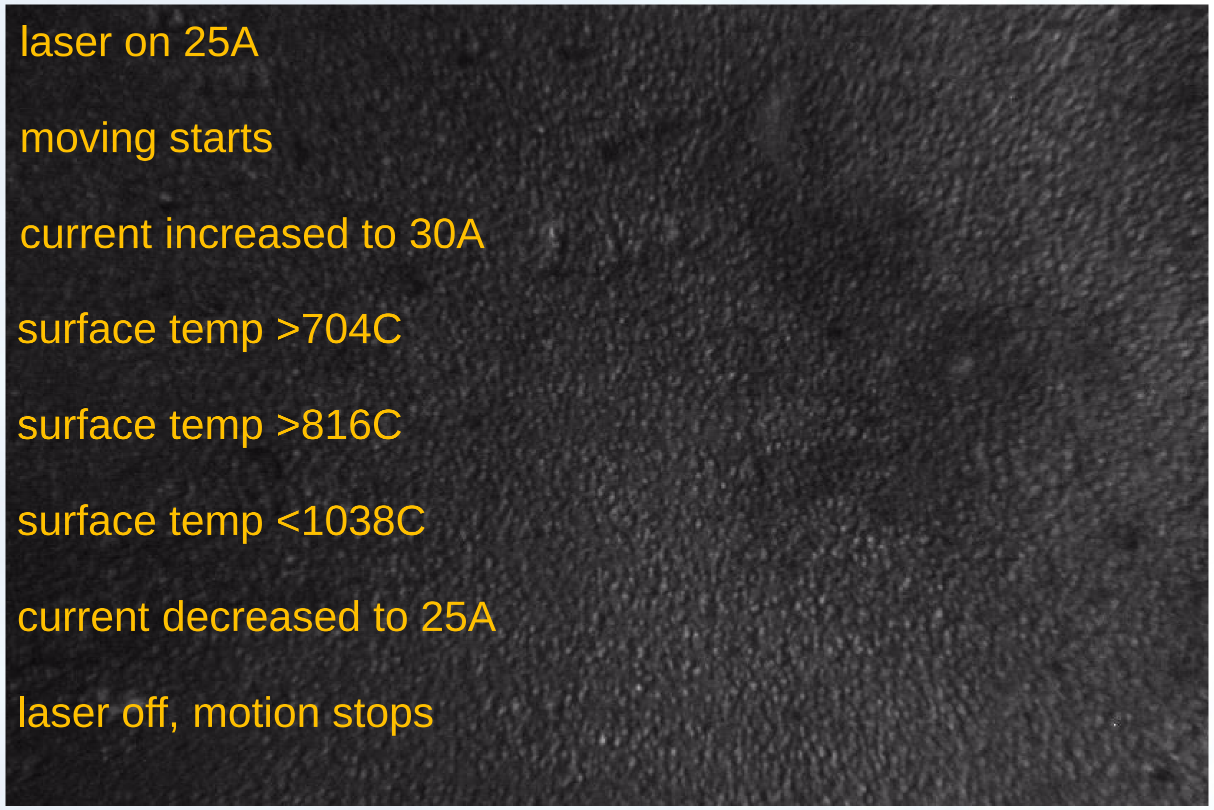
Comparable Sunlight:
12 mW/cm^2

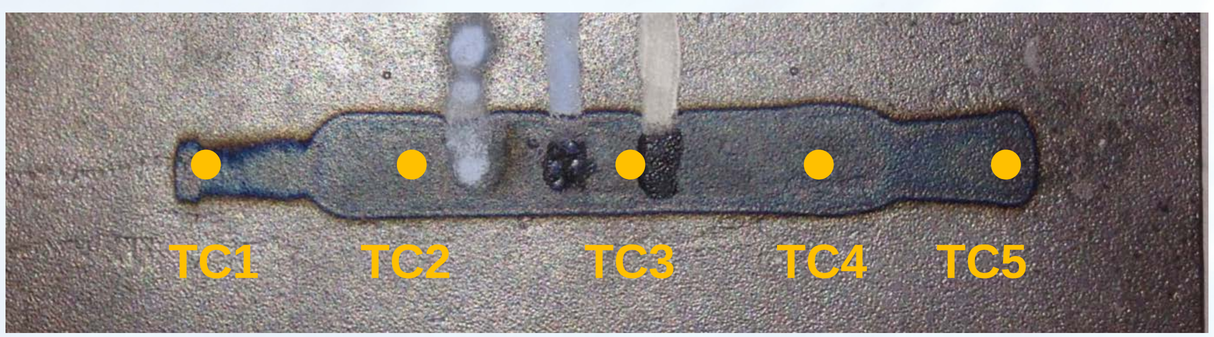


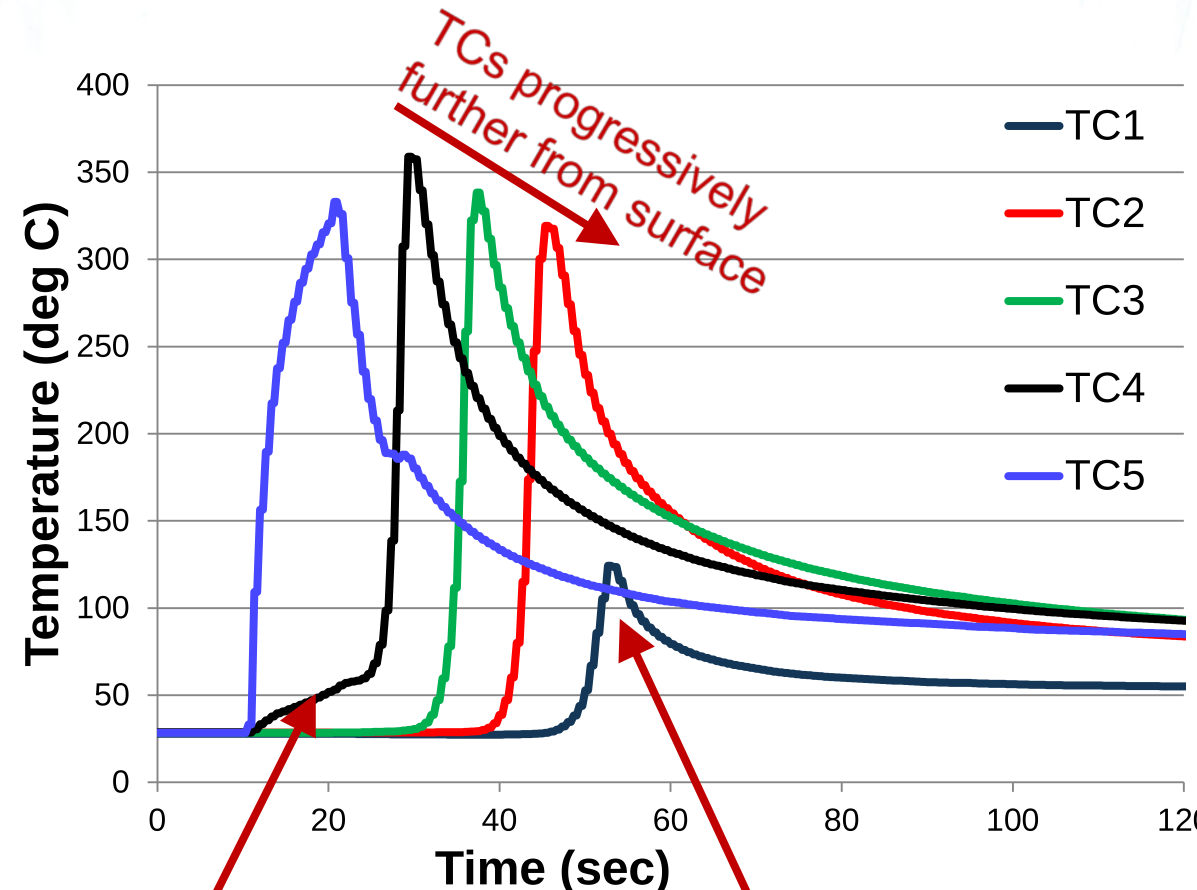
At 1m
(approximate position of worker)

Start with the Best First…

After 33 trials (many good), the last data run may contain the most valuable data.







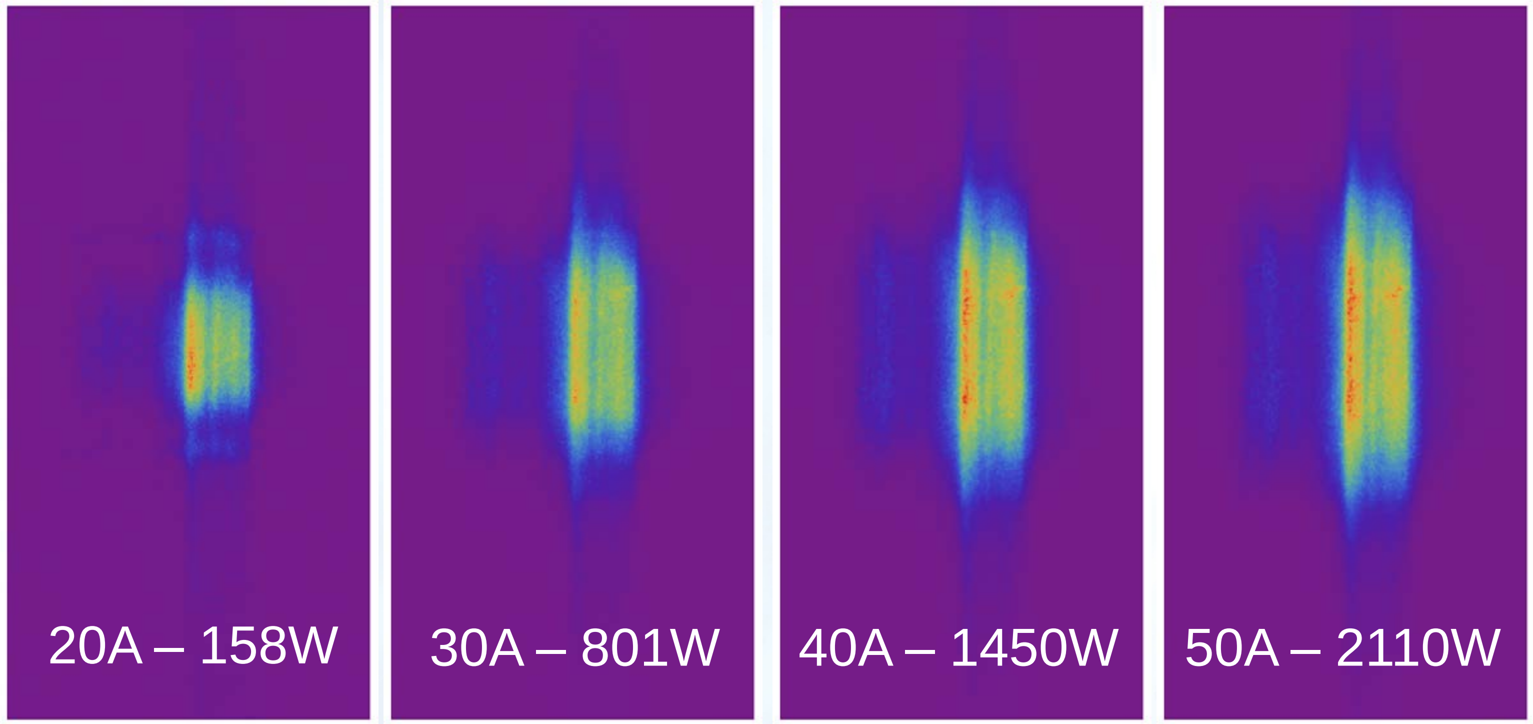
Multiple effects here: preheating (10-20 sec), motion starts (@20 sec), current increased (@23 sec)

Laser never fully reached TC1

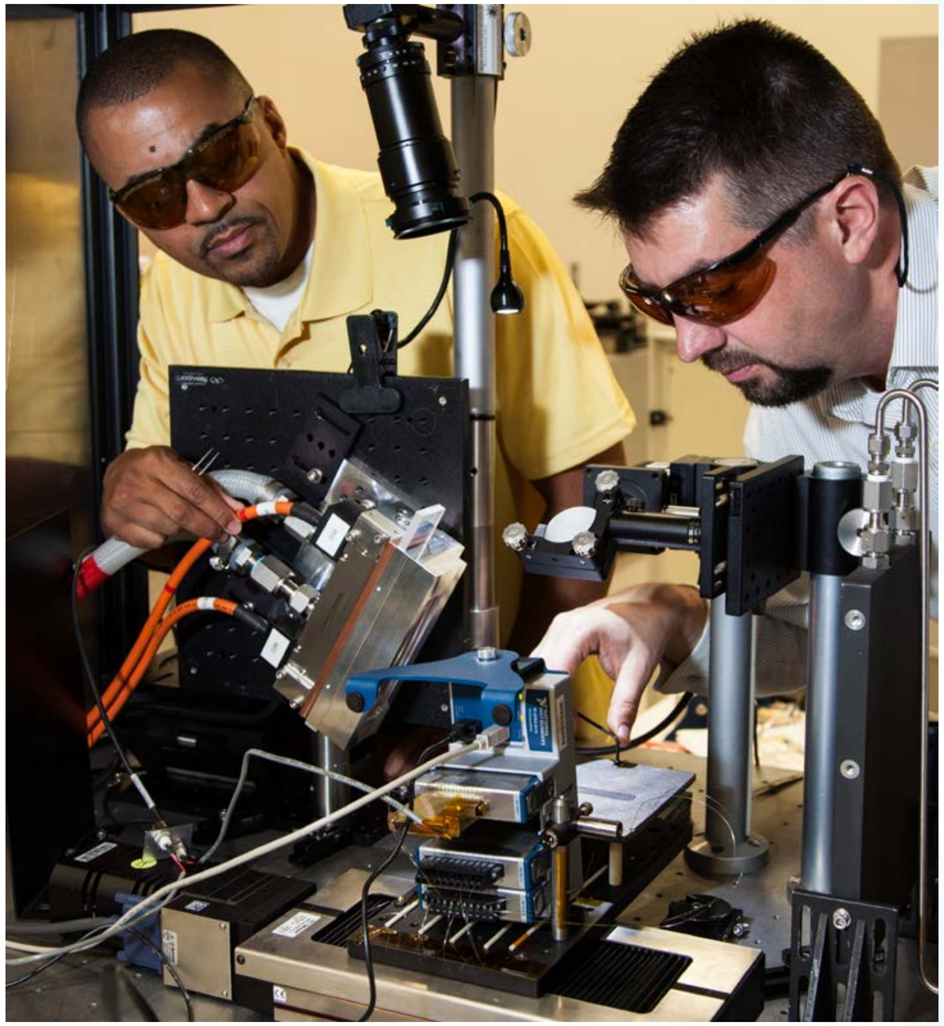
This is hypothesized as potentially an optimal set of conditions: high welding rate (200 MMPM), bulk temperatures ~300C, no surface melting (>816C but <1038C), heated width comparable to tool diameter.

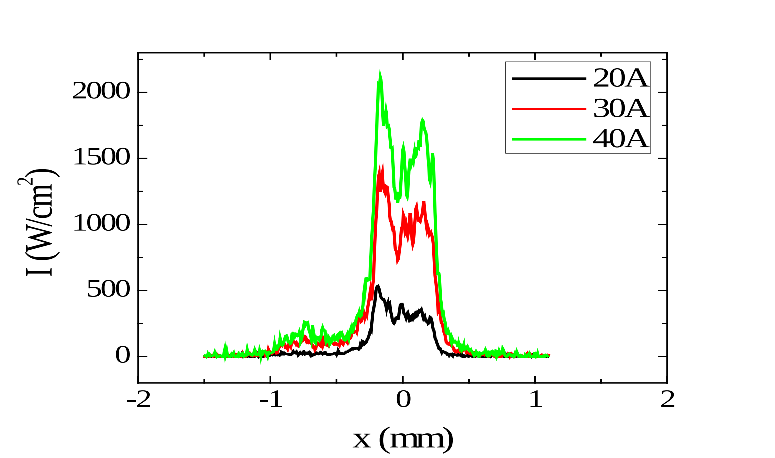
Beam Measurements

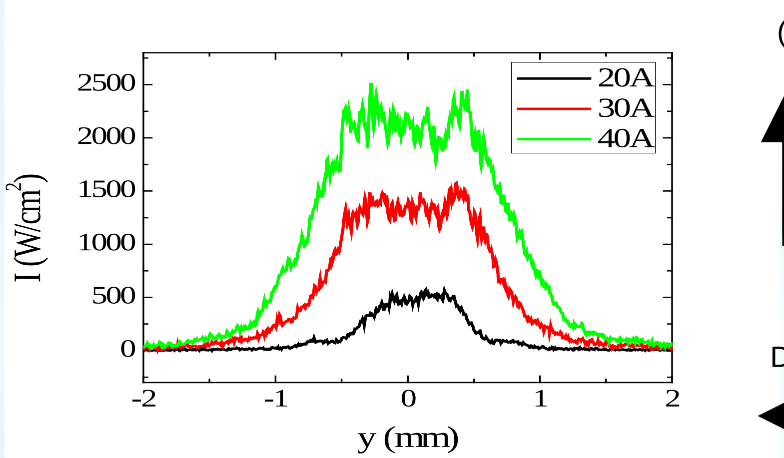
It became quickly apparent that the 5 kW diode array was more than sufficient for preheating needs so 20-30 Amps became the target operating band.

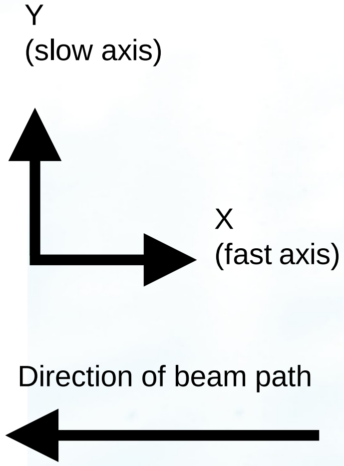


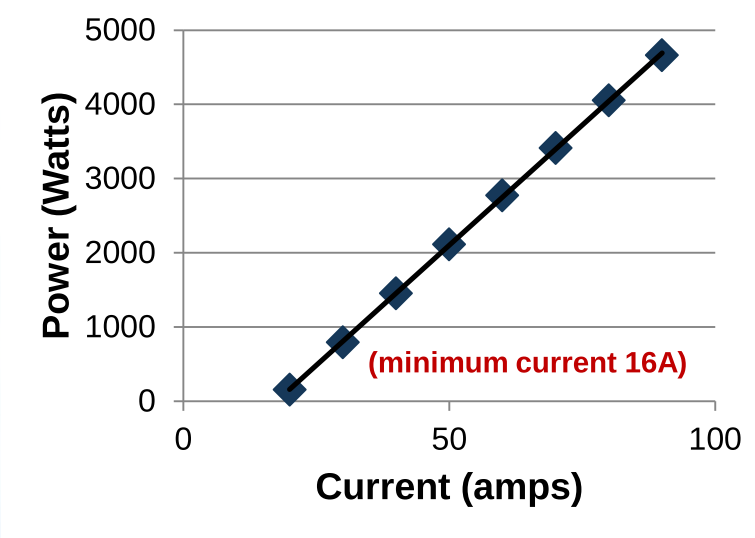
(all beam measurements taken on a beam dump)





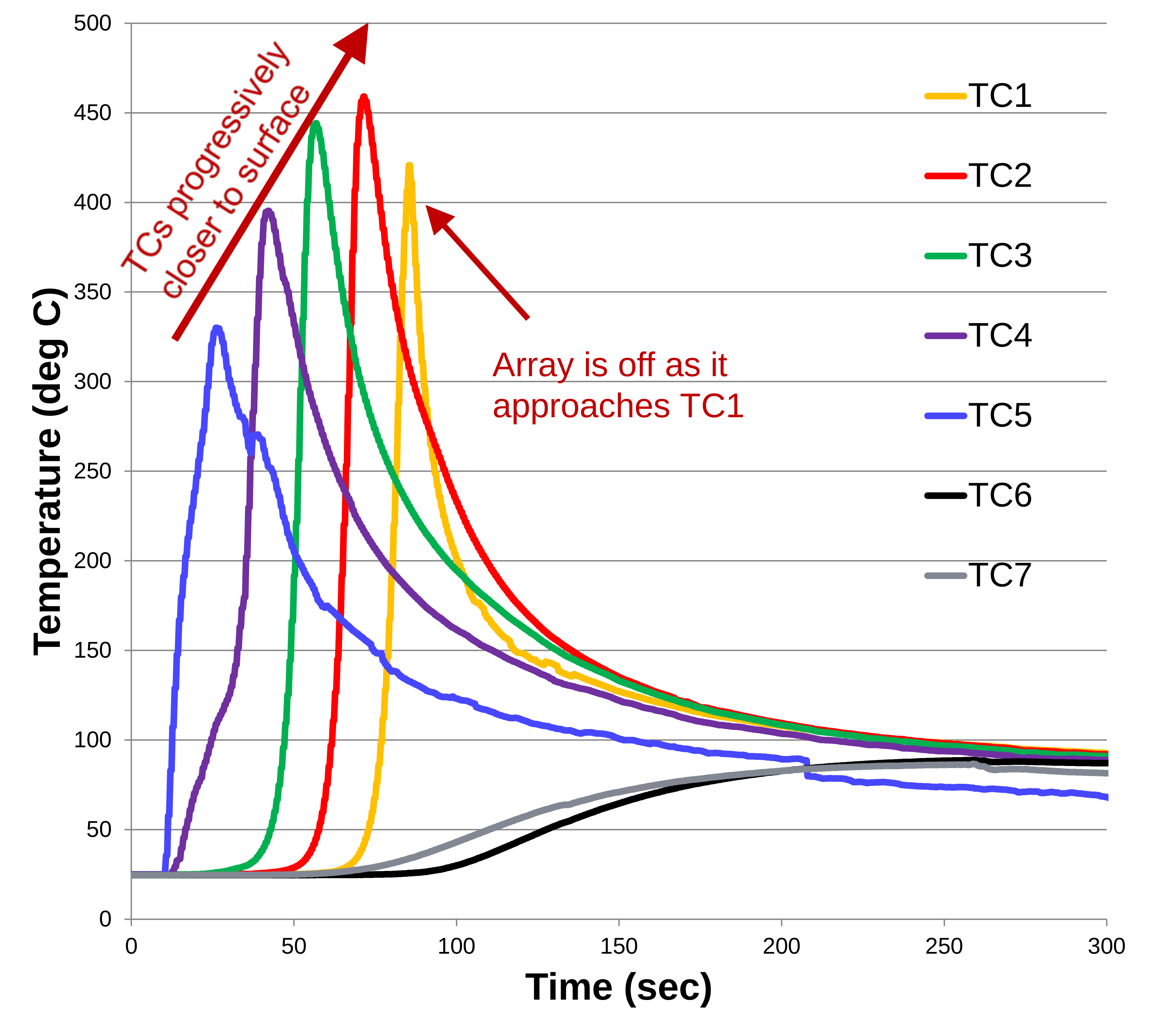






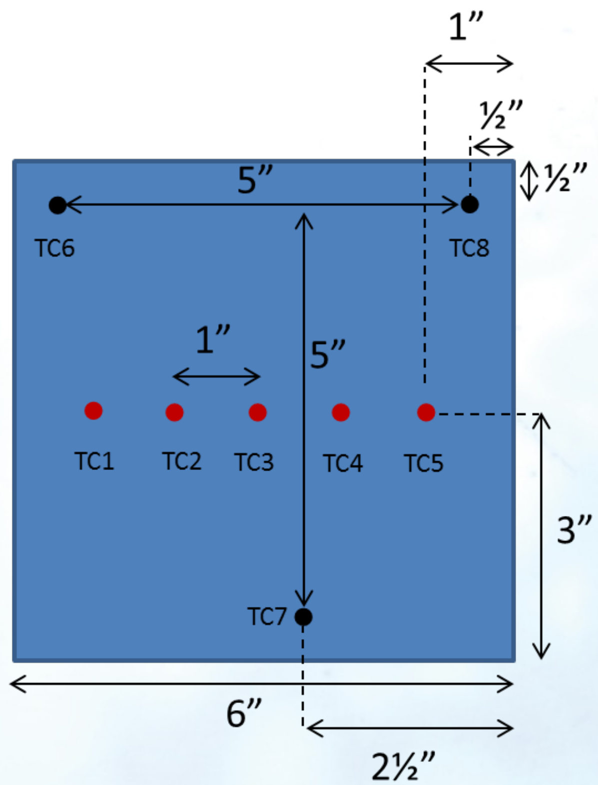
Thermocouple Response

140725a:
10 sec delay, 30A, 1.667 mm/sec, total distance 101.6 mm



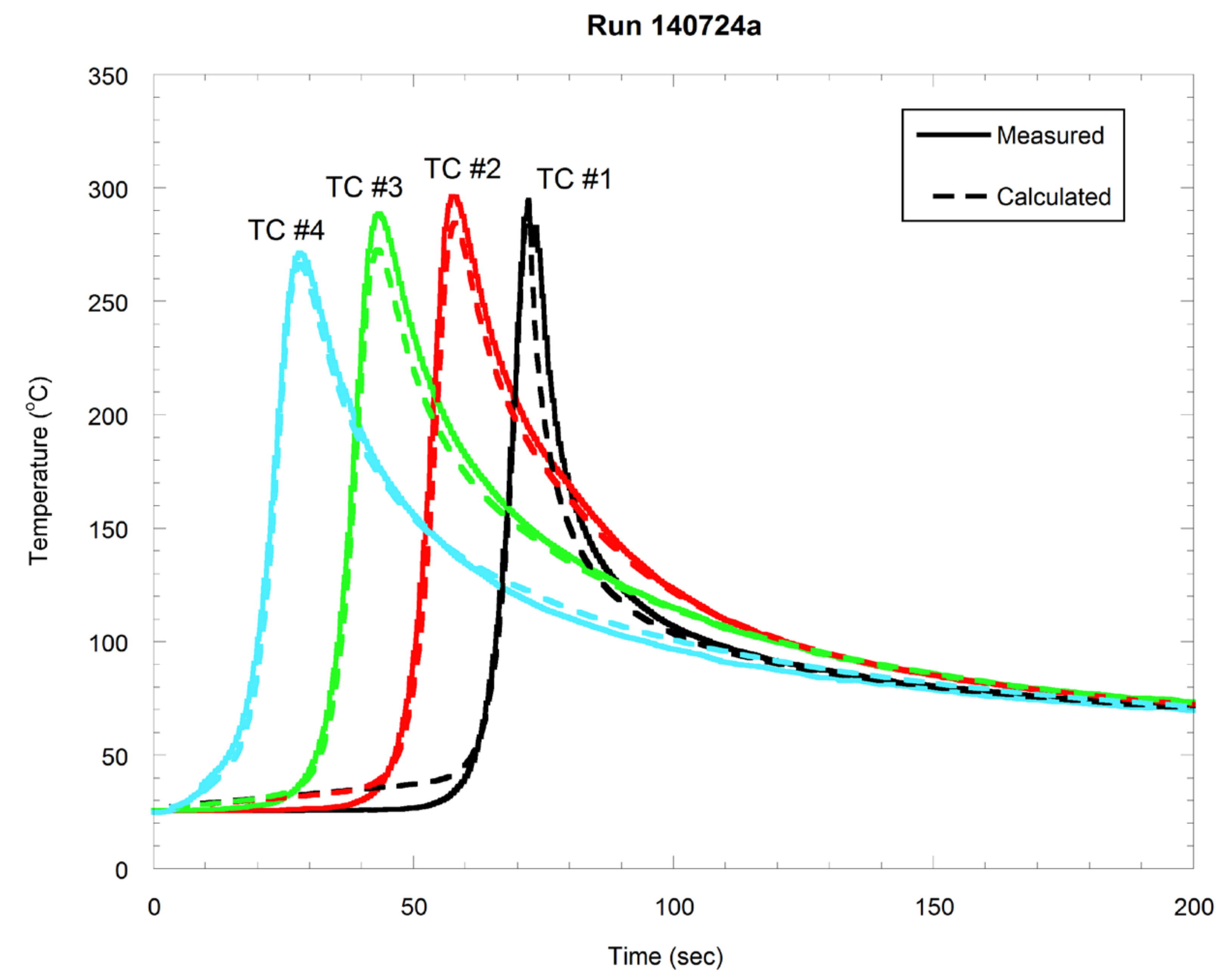
Several notable trends:

- Each TC reaches a peak in a similar manner
- z dependence is shown
- TC7/6 are distant and heat slowly despite being on the surface



Experimental to Modelling Data

Thermal response of HY80 was modelled using FlexPDE. Material properties of HY80 as a function of temperature were included. Absorption was maintained constant at 0.64.

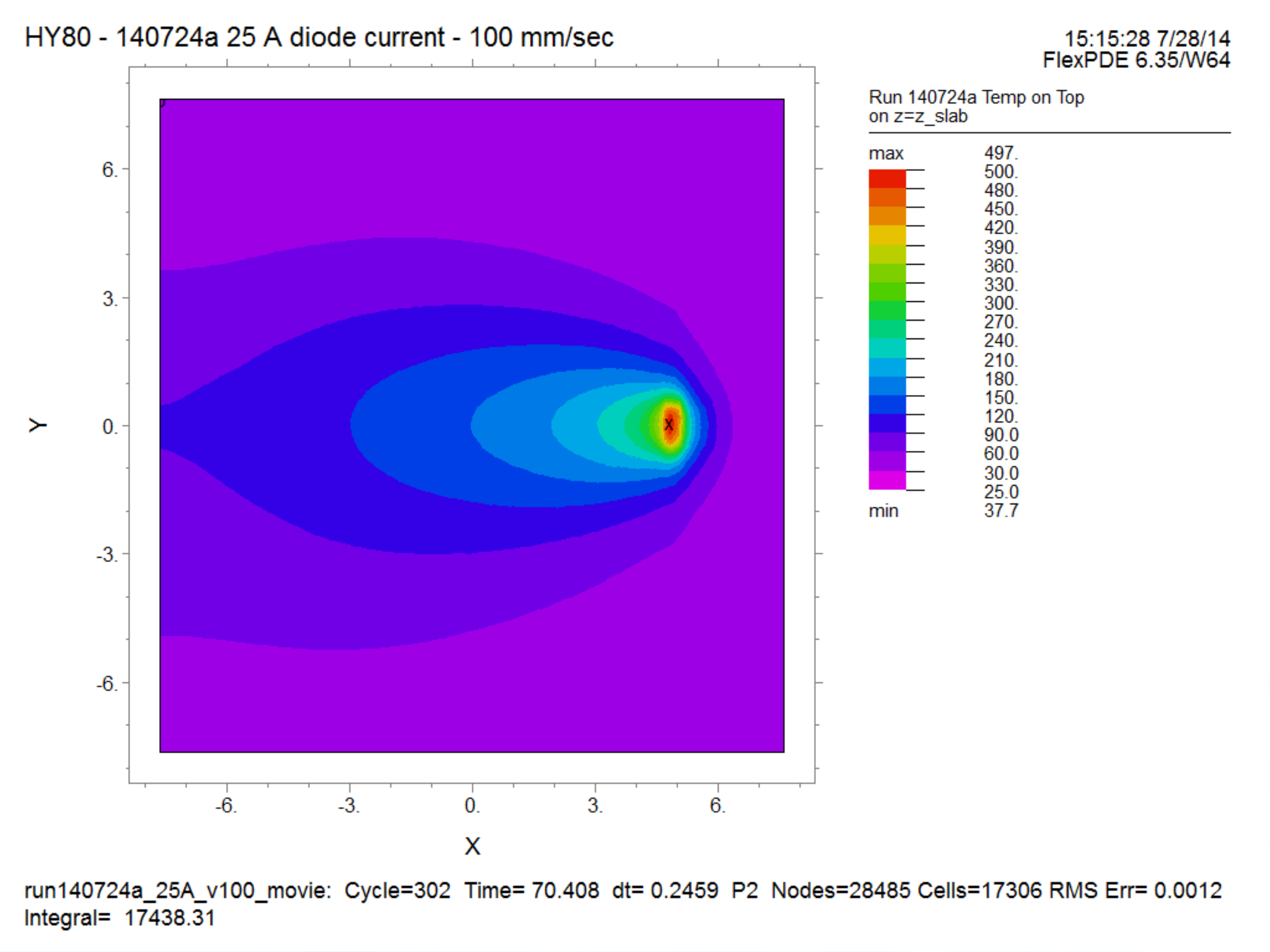


At 25A calculated data matched very closely to measure data.

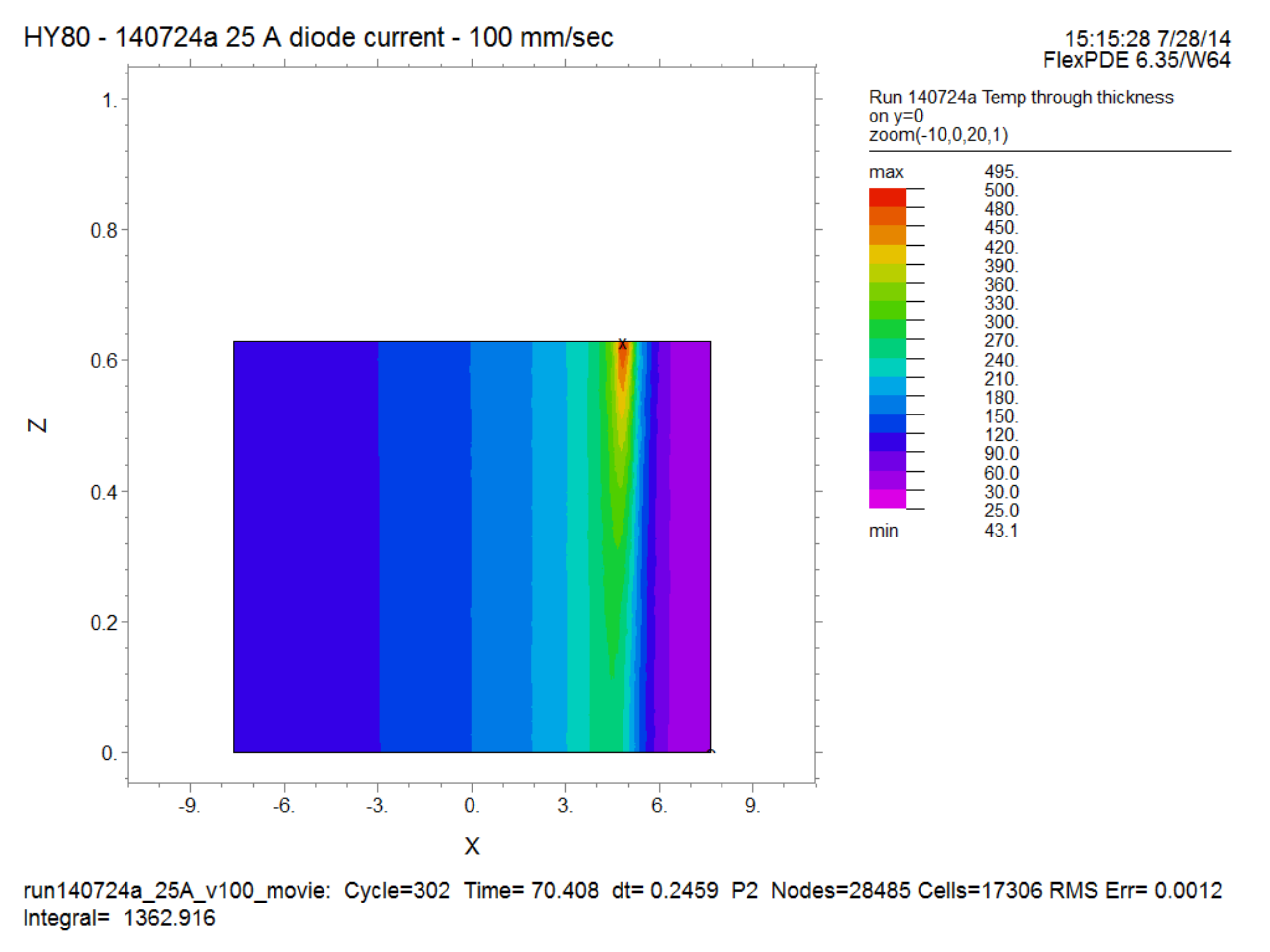
Reasonable results were also obtainable with COMSOL.

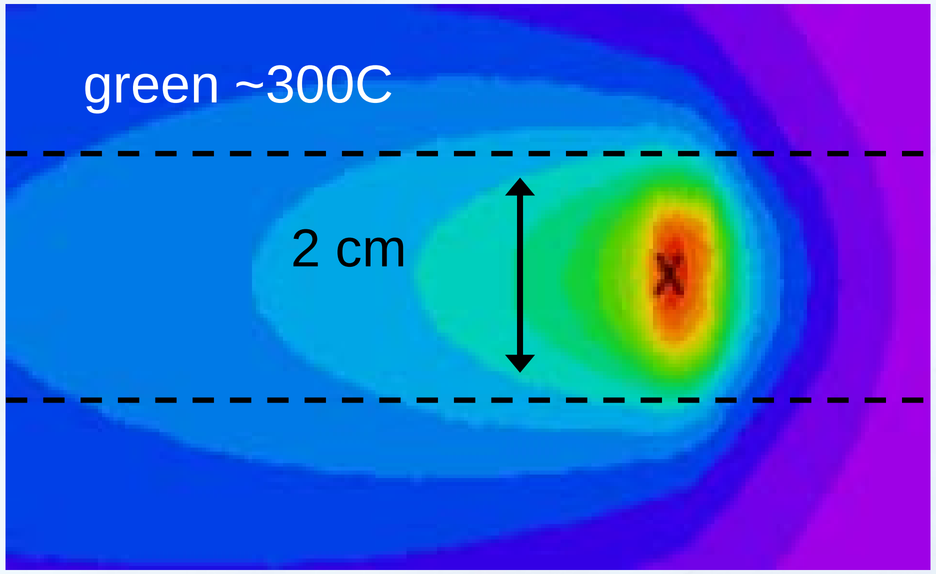
Experimental to Modelling Data

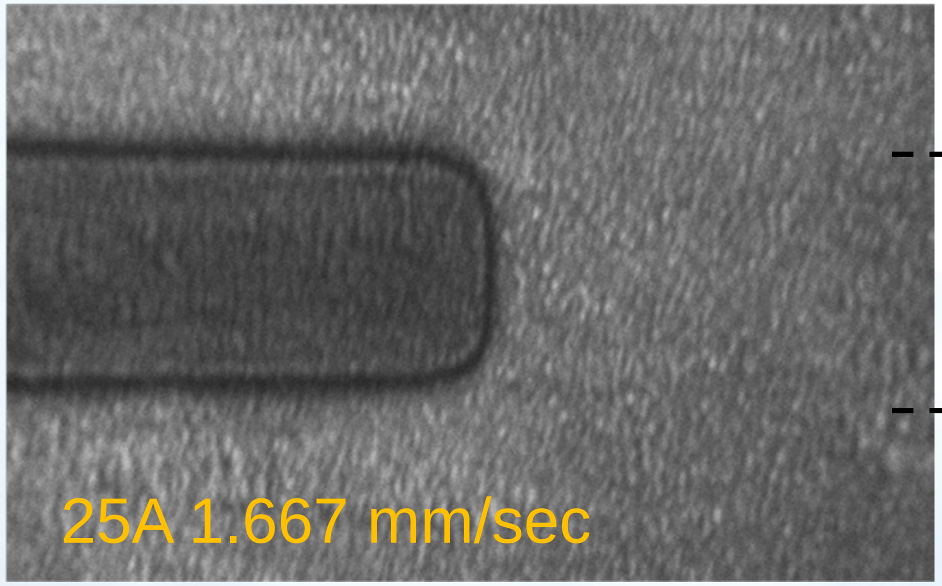
Planar view (x-y)

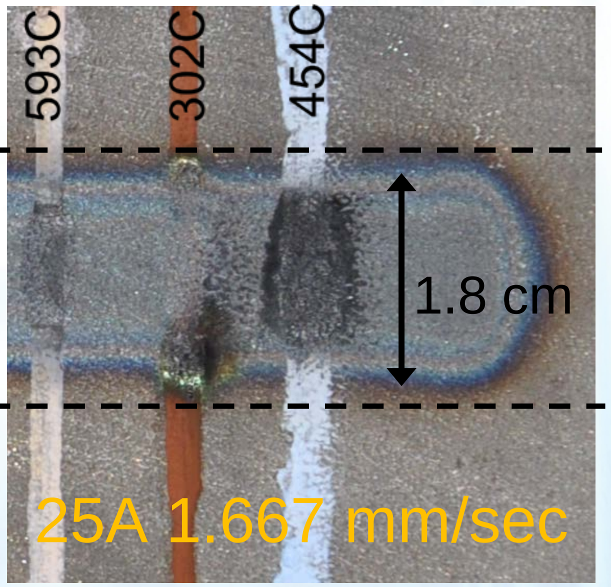


Transverse view (x-z)

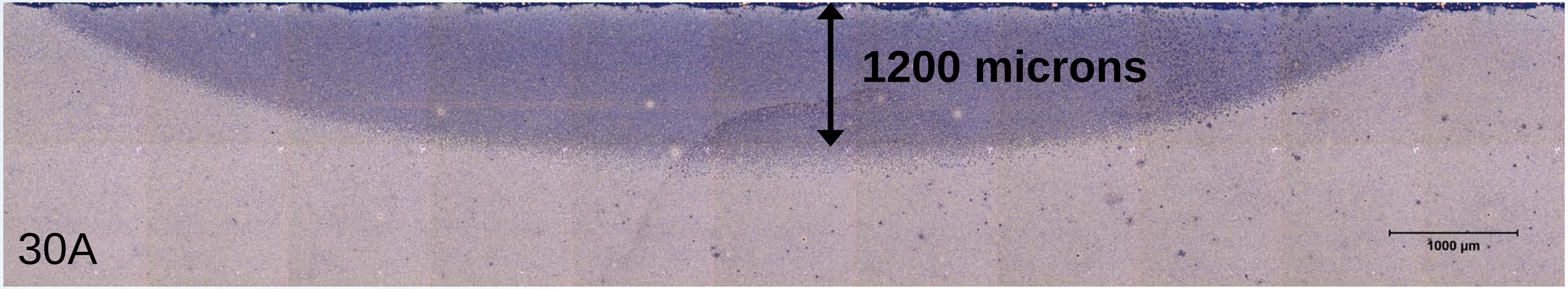


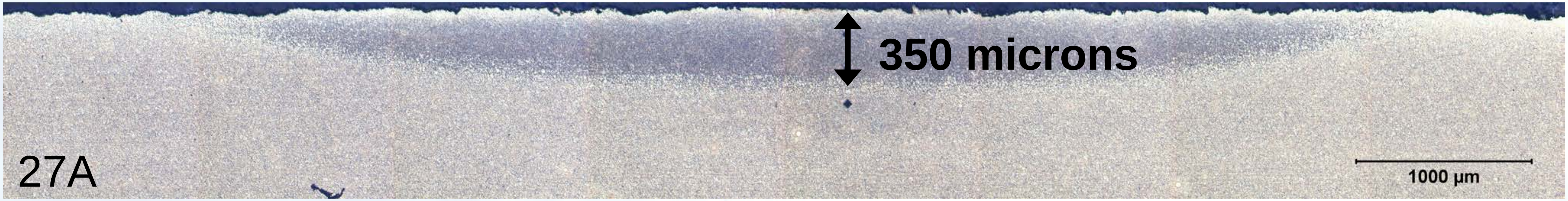


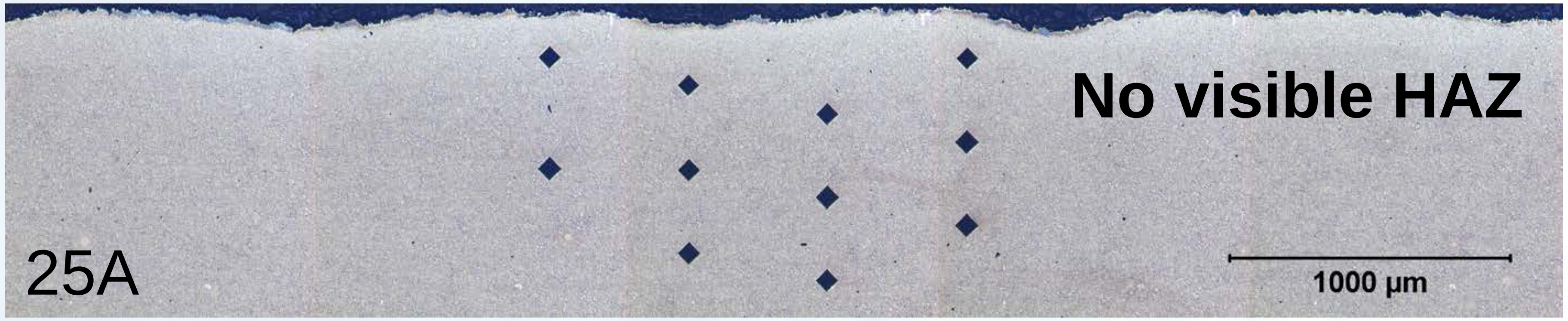




Material Characterization



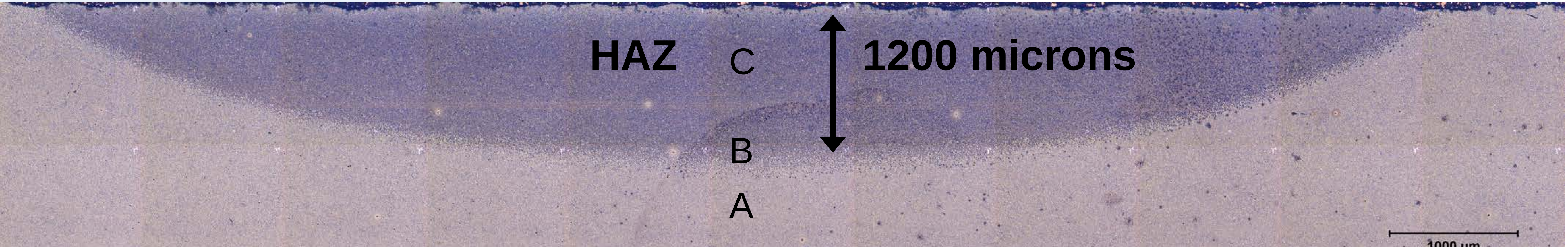




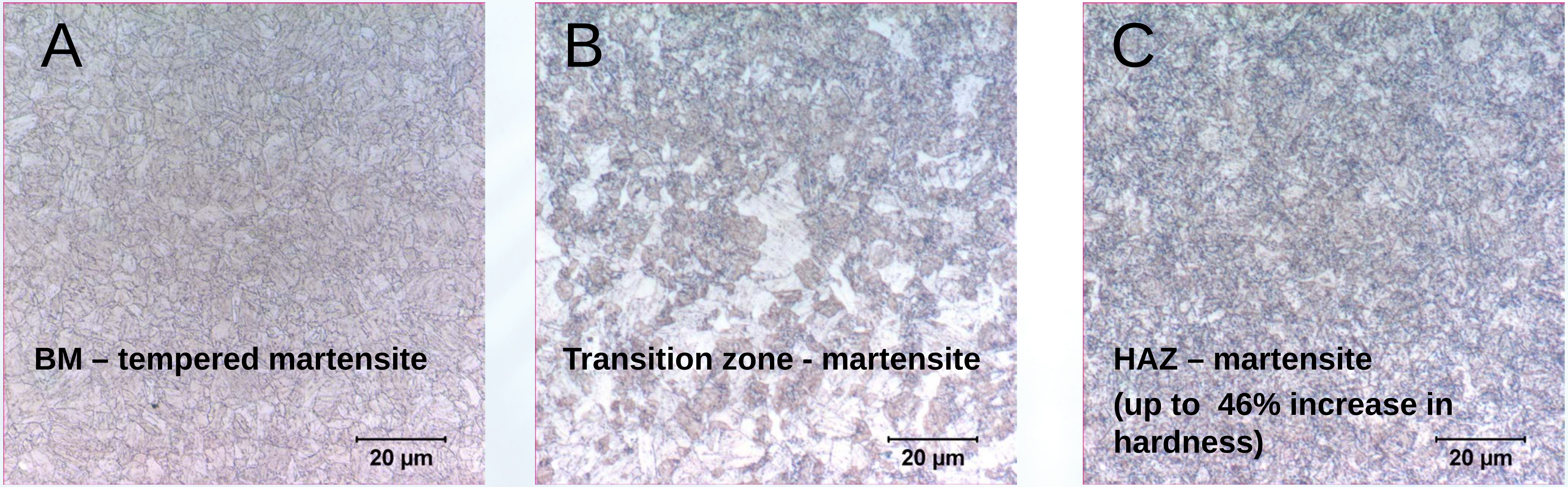
Laser heating at lower currents (25A) caused almost no noticeable change in microstructure and little change in hardness.

Material Characterization

30A Transverse Section (laser heating alone)

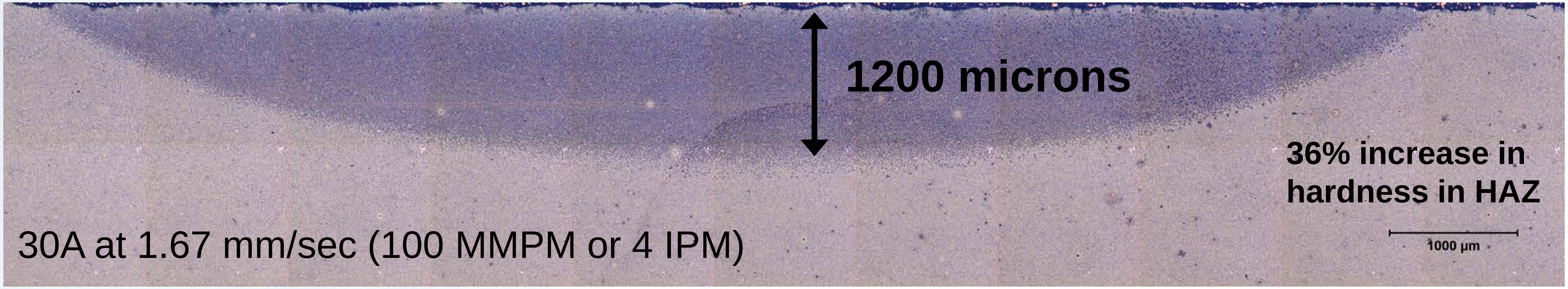


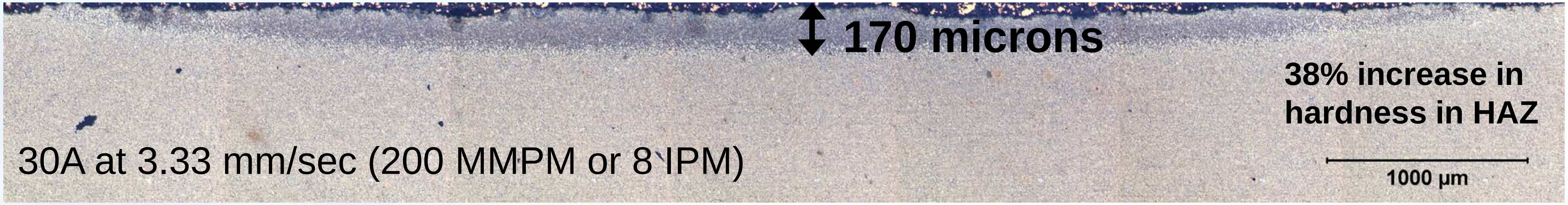
HY80: 0.18% C, 1.8% Cr, 3.25% Ni, 0.6% Mo, 0.4% Mn, 0.25% Cu, balance Fe



Laser heating at 30A caused a shallow HAZ that consisted of an increased amount martensite and a resultant increase in hardness.

Material Characterization





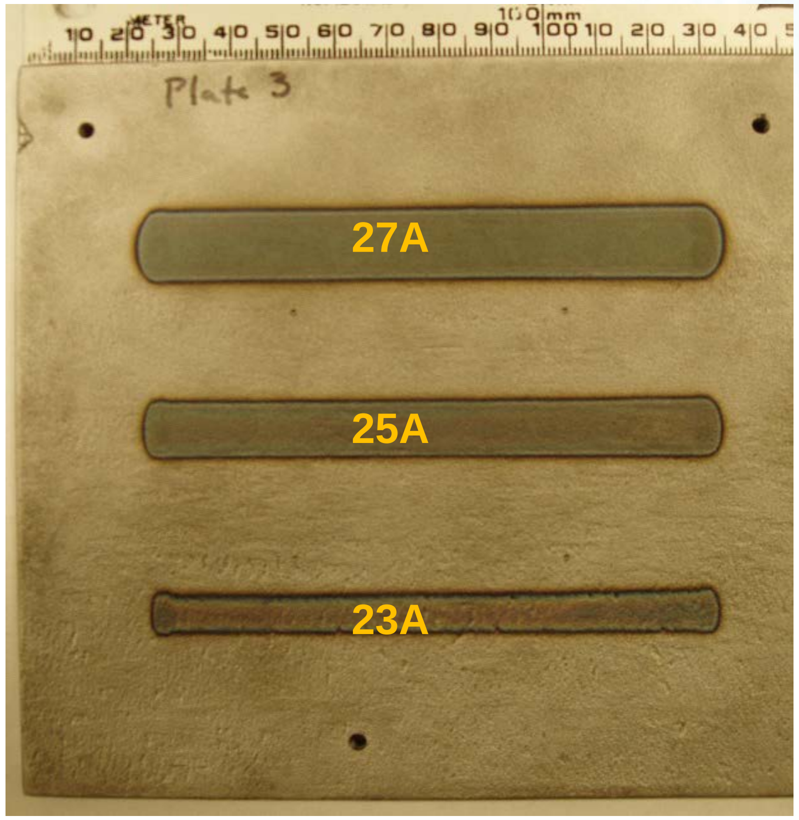
As expected, increasing the traverse rate reduces the size of the HAZ considerably. Related research has shown that 400 RPM and 100 MMPM is an optimal combination for traditional FSW on HY80.

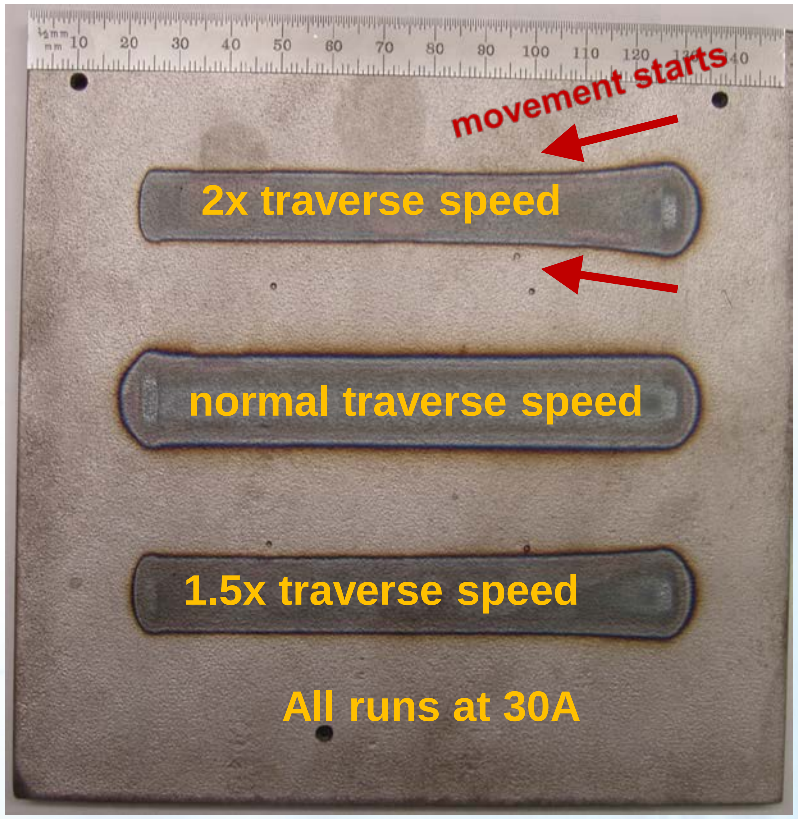
With DLAFSW the following are considered possible:

- Operation at standard traverse rates with reduced tool wear
- Operation at increased traverse rates
- Operation at considerably lower rotational rates

Summary of Current Work

- ✓ Parameters of the 5 kW diode array determined on a beam dump (power and beam size vs current).
- ✓ Scattering of diode light determined.
- ✓ Heating capability of the diode array on HY80 both stationary and moving determined.
- ✓ Temperature field following diode laser heating determined experimentally by multiple means for both stationary and moving conditions.
- ✓ Modeling of temperature response of workpiece closely matches experimental data.
- ✓ Operational parameters of diode laser determined for future use in a DLAFSW setup.
- ✓ Material response due to laser heating alone determined.





Future Work and Concepts

- ❑ Design and construction of an operational DLAFSW setup is in progress at Naval Surface Warfare Center Carderock Division (NSWCCD)

- ❑ Conduct DLAFSW on HY80 to demonstrate:
    - Feasibility of using HPDLs for hybrid FSW
    - Reduction in frictional forces during FSW of steels

- ❑ Consider post-heating as well as pre-heating

- ❑ Consider FSW schemes which could join hardenable steels below the A1 temperature

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WARFARE CENTERS
Carderock Division

Goal: improve tool life and/or increase tool traverse speed specifically for FSW of steels

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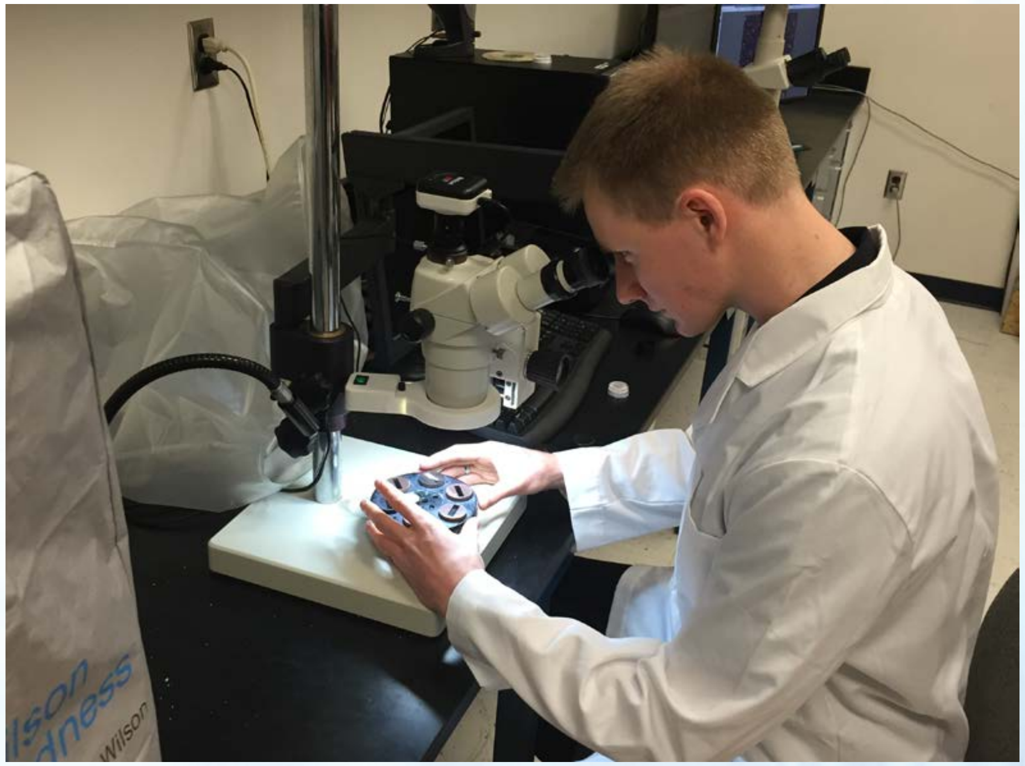

Questions?

Diode Laser Assisted Friction Stir Welding (DLAFSW):

Improving FSW tool performance and welding speed by controlled laser preheating.

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