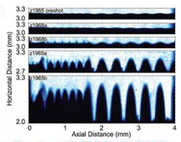
SAND2020-2500C

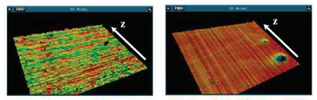
Understanding Electrothermal Instability Growth by Comparing Z-Pinches with Engineered Defects to 3D-MHD Simulations

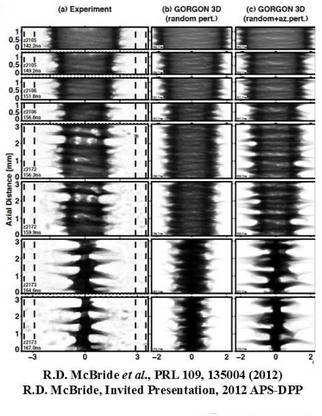
T.J. Awe, E.P. Yu, T.M. Hutchinson, B.S. Bauer, K. Tomlinson, D.A. Yager-Elorriaga, M.W. Hatch, G.A. Shipley, B.T. Hutsel

Z experiments have focused on developing predictive models of instability growth on imploding liners



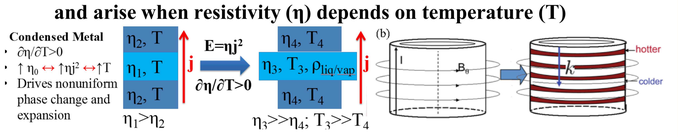
D.B. Sinars *et al.*, Phys. Rev. Lett. 105, 185001 (2010)
D.B. Sinars, Invited Presentation, 2010 APS-DPP



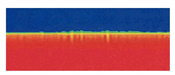


R.D. McBride *et al.*, PRL 109, 135004 (2012)
R.D. McBride, Invited Presentation, 2012 APS-DPP

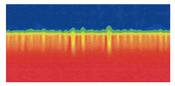
Electrothermal instabilities are driven by Joule heating and arise when resistivity (η) depends on temperature (T)



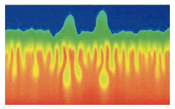
2D simulations show ETIs develop after melt and seed later MRT growth



Locations of higher Joule heating vaporize & expand first→Density perturbations form

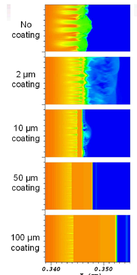


The Magneto-Raleigh Taylor (MRT) instability grows from the ETI seed, and begins to dominate



Non-linear MRT growth redistributes liner mass; large amplitude perturbations persist and grow

But, ETI-driven density perturbations are mitigated with dielectric surface coatings!

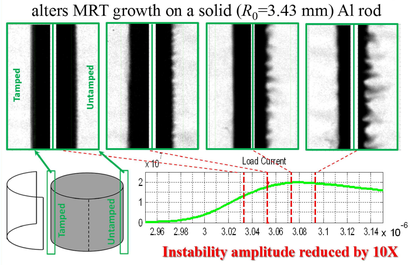


Thick (>10 μm) insulating coatings mitigate effects of ETI and reduce seed for MRT growth

No ETI strata in the dielectric

Mass redistribution from ETI is significantly tamped by the coating
– Reduces seed for MRT growth
– Reduces integral instability growth

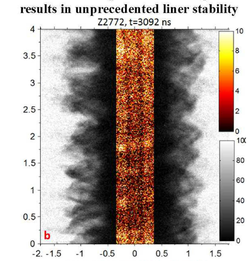
Adding a 70-micron-thick dielectric tamper dramatically alters MRT growth on a solid (R_0=3.43 mm) Al rod



Instability amplitude reduced by 10X

K.J. Peterson, *et al.,* PRL **112**, 135002 (2014)

Combining axial premagnetization with a dielectric tamper for ETI mitigation results in unprecedented liner stability



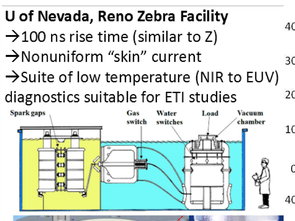
CR=R_{in}(t=0)/R_{in}(t)=21!

T.J. Awe, *et al.,* PRL **116**, 065001 (2016)

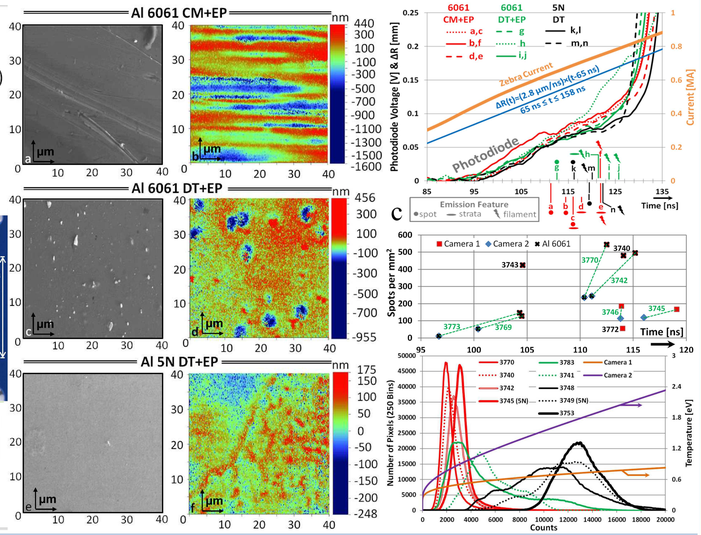
The early nonuniform Joule heating of Z liners is not diagnosed. Rather, ETI development is inferred by evaluating MRT late in the experiment. ETI is NOT directly observed!

Nonuniform Joule heating is observed with unprecedented diagnostic resolution

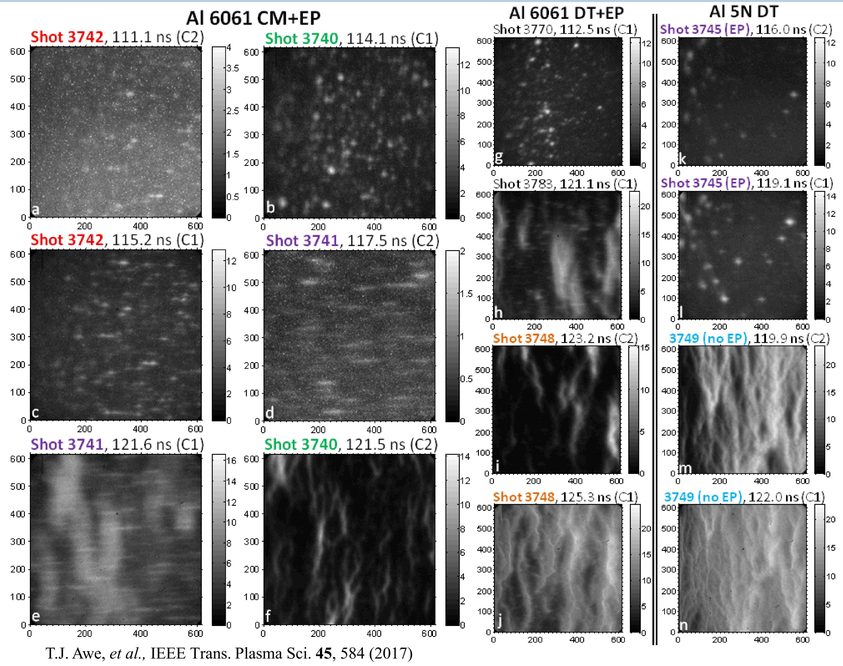
U of Nevada, Reno Zebra Facility
→100 ns rise time (similar to Z)
→Nonuniform "skin" current
→Suite of low temperature (NIR to EUV) diagnostics suitable for ETI studies



2 frame gated imager: 2 ns and 3 μm resolution



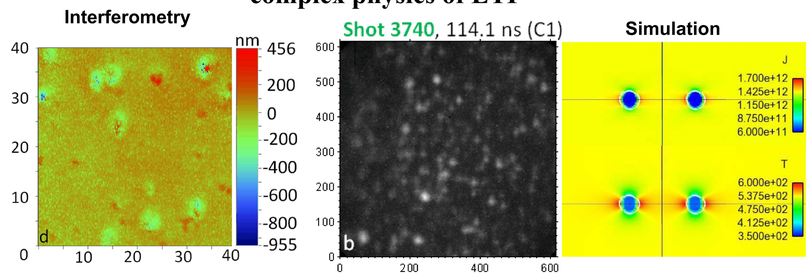
DT → Diamond Turned CM → Conventionally Machined EP → Electropolished



T.J. Awe, *et al.,* IEEE Trans. Plasma Sci. **45**, 584 (2017)

For Al 6061 alloy, newly observed early phenomena include overheated azimuthally stretched elliptical spots (20-40 μm wide by 10 μm tall) and distinct strata (40-100 μm wide by 10 μm tall). Data give credence to the hypothesis that early nonuniform Joule heating, including ETI, may provide the dominant seed for MRT

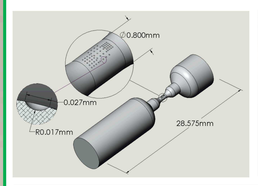
Advanced targets and simulations are required to unravel the complex physics of ETI

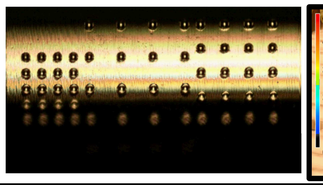


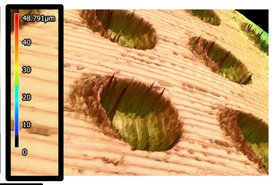
Modeling ETI is a significant challenge—Comparative dataset must be unambiguous

- **Off the shelf metals contain extremely complex resistive inhomogeneities, making detailed comparison with simulation nearly impossible**

Using Slow Tool Servo on a diamond lathe with X,Y,Z and C Axis control, it is possible to create very precise arrays of micron scale semi-hemispherical pits



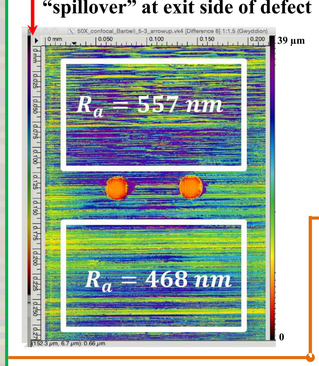


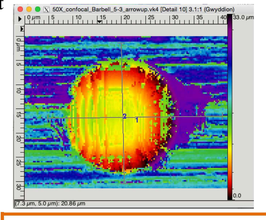


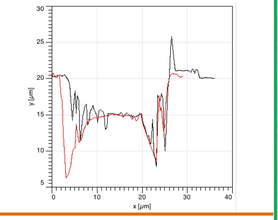
Side at 0 degrees					Side at 180 degrees				
# of defects	diameter	depth	axial c-to-c	arc length c-to-c	# of defects	diameter	depth	axial c-to-c	arc length c-to-c
2	12 um	3 um	0	36 um	2	12 um	3 um	0	72 um
2	12 um	3 um	36 um	0	2	12 um	3 um	72 um	0
2	24 um	6 um	0	72 um	2	24 um	6 um	0	144 um
2	24 um	6 um	72 um	0	2	24 um	6 um	144 um	0
2	24 um	6 um	72 um	72 um	2	24 um	6 um	144 um	144 um
2	48 um	12 um	0	144 um	2	48 um	12 um	0	288 um
2	48 um	12 um	144 um	0	2	48 um	12 um	288 um	0

Simple patterns will be studied first to avoid confusing global versus local current density modifications

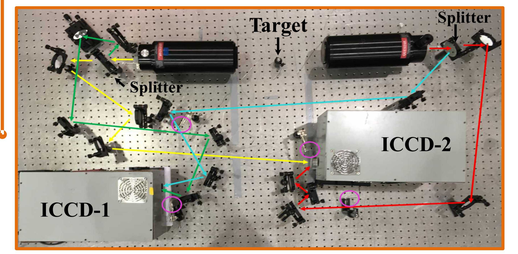
First set of loads match defect dimensions well but are rougher than desired and have "spillover" at exit side of defect







Novel dual-view/4-frame imaging system will study defect evolution—See poster 4P51, M.W. Hatch, this session



This work was funded in part by Sandia's Laboratory Directed Research and Development Program (Projects No. 178661 and No. 200269)