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Mesoscale Thermal Transport Measurements of Multi-phase Nuclear Fuels Using a Square-wave Pulse Thermoreflectance Technique

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Background

- Accurate determination of thermal conductivity (*k*) in fresh and irradiated nuclear fuel materials requires a measurement technique with mesoscale resolution
- New technique uses modulated pump/probe lasers to excite/monitor surface temperature of gold coated polished sample; convolved spot size (~2 μm)
- Pump laser triggered by square-wave signal from function generator, and photodetector and digital oscilloscope used to collect and record probe signal

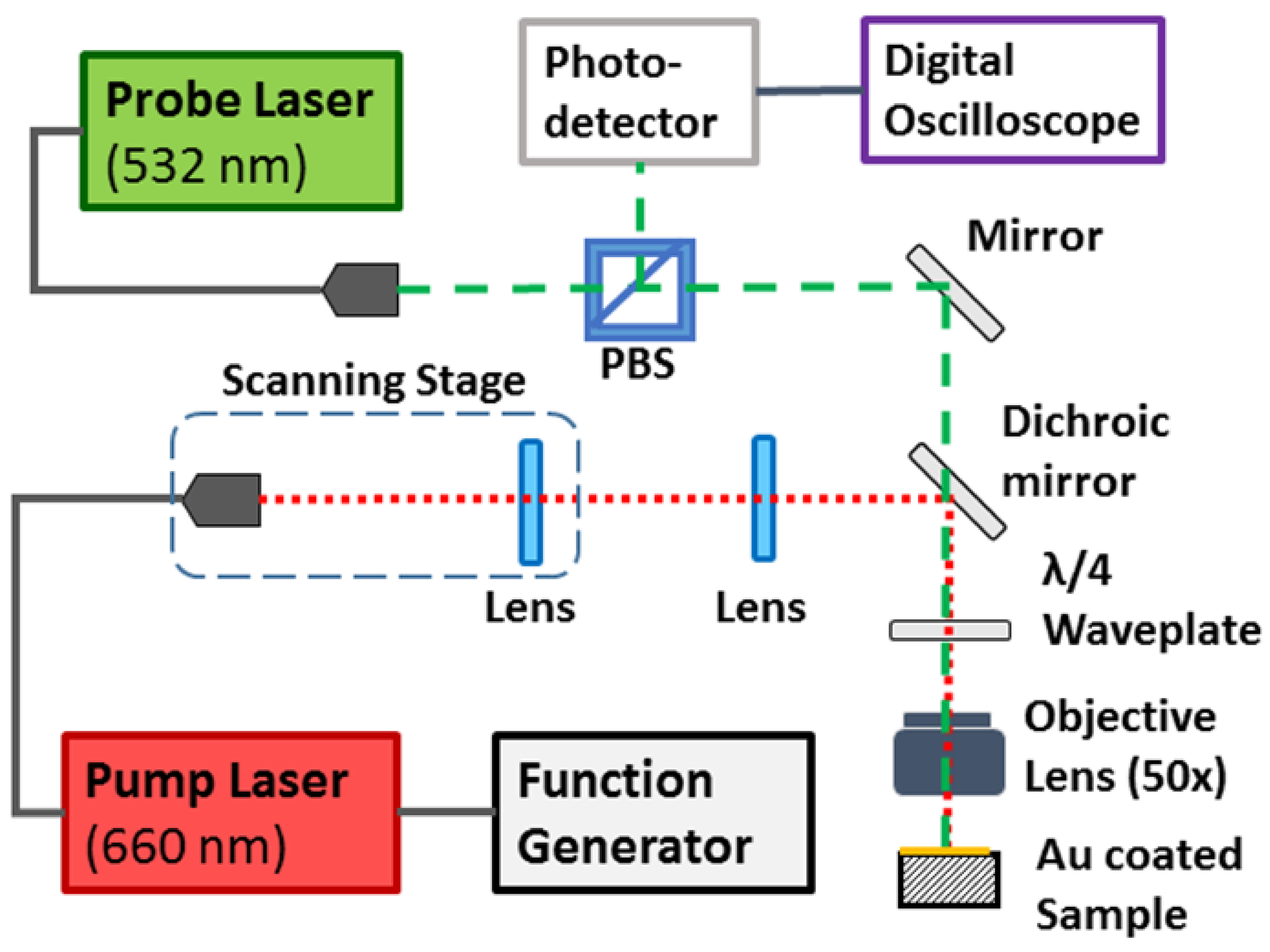


Fig. 1. Squarewave-pulse thermoreflectance experiment configuration diagram. A 660 nm pump laser is used to heat the surface of a gold coated sample (a~100 nm thick) and a 532 nm probe laser detects the surface temperature from which the thermal diffusivity can be calculated.

Experimental Methods

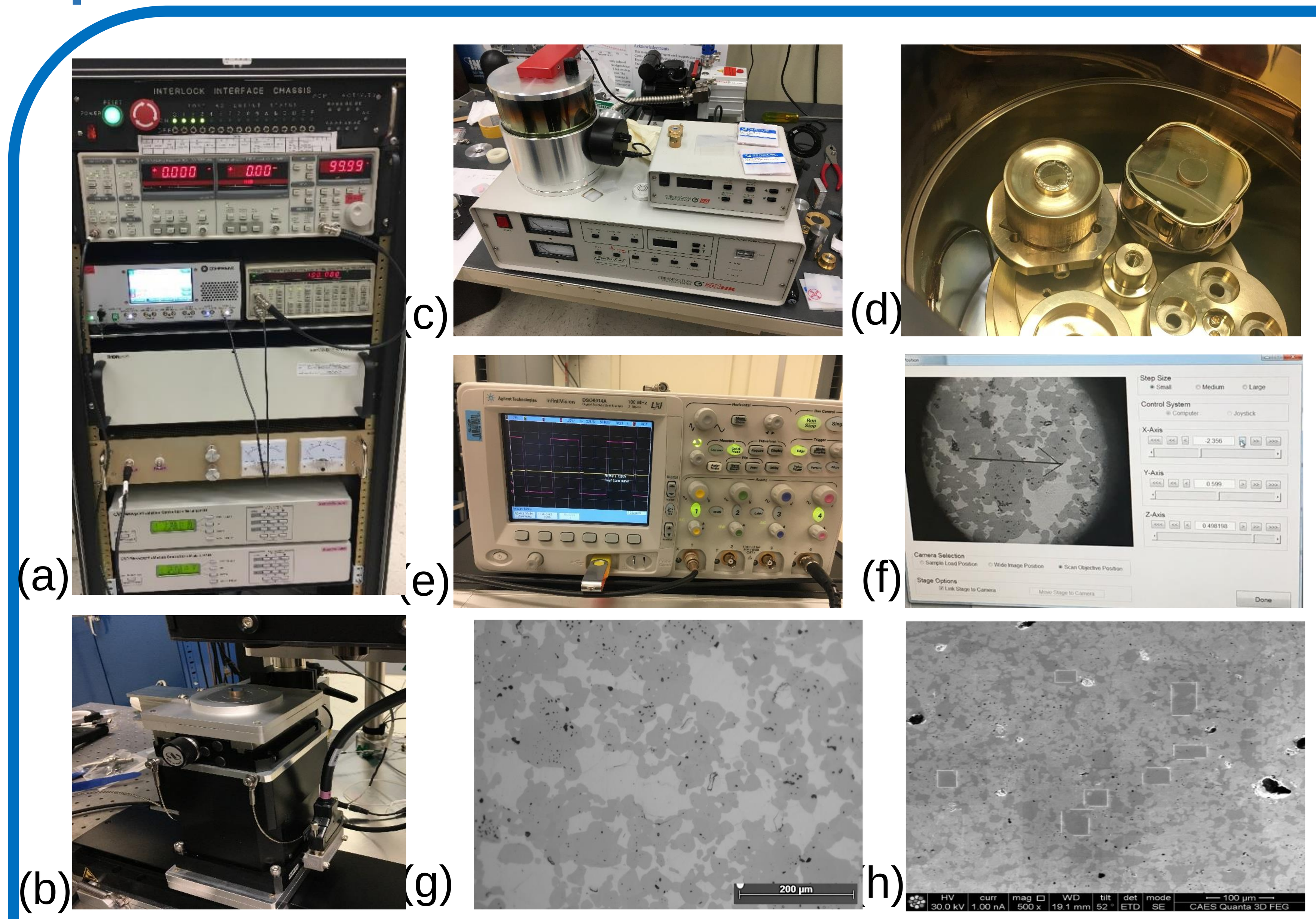


Fig. 2.(a) Thermal conductivity microscope instrument chassis (b) Motorized sample stage and focus objective (c) Sputter coater (d) planetary stage with gold coated samples (e) digital oscilloscope for (f) Matlab based user interface (g)1000x optical image of UN/U_3Si_2 (70/30 vol%) polished specimen (UN=dark U_3Si_2 =light) (h) 500 x SE image of same sample with UN (light) and U_3Si_2 (dark) phases

Results

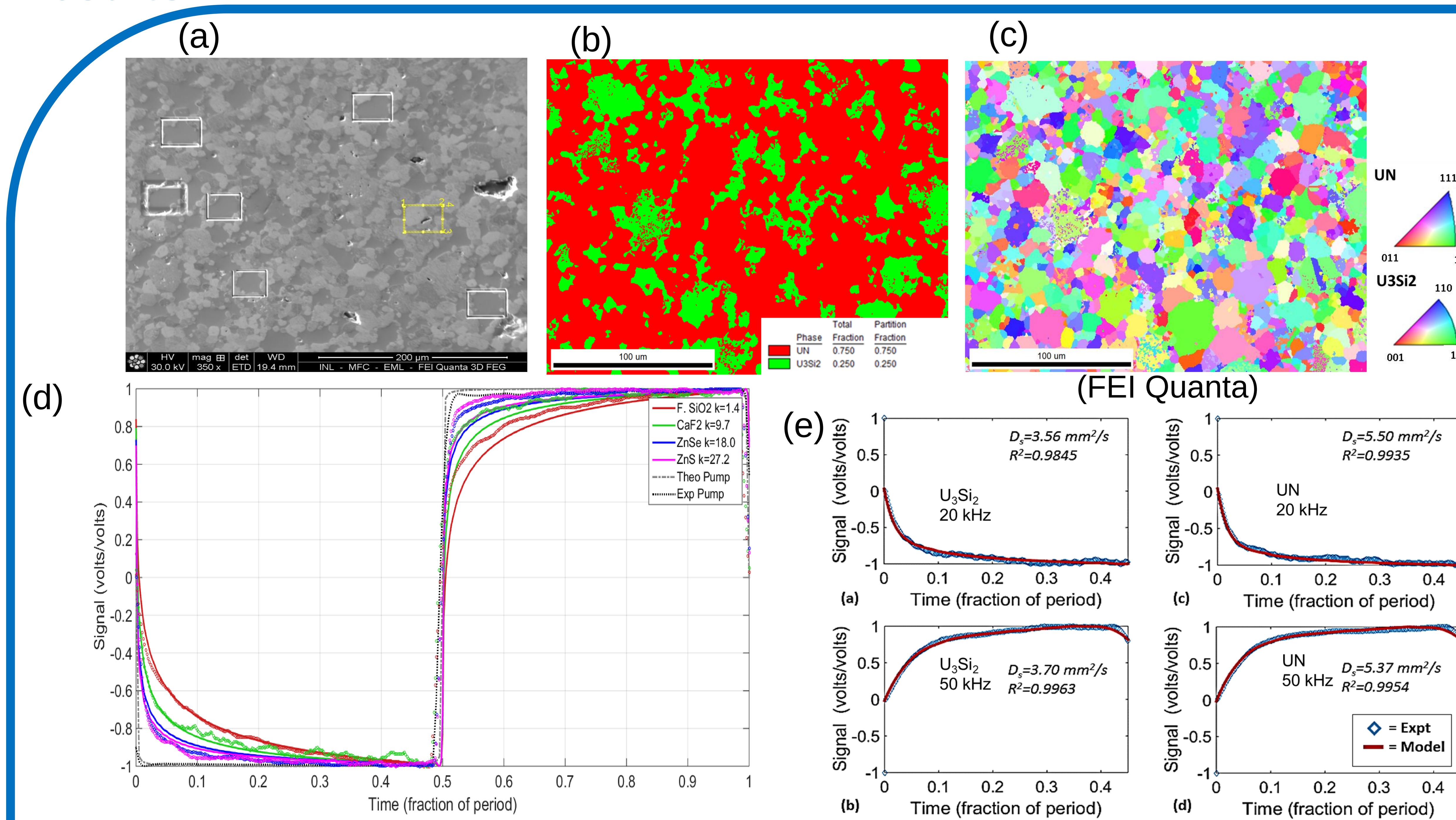
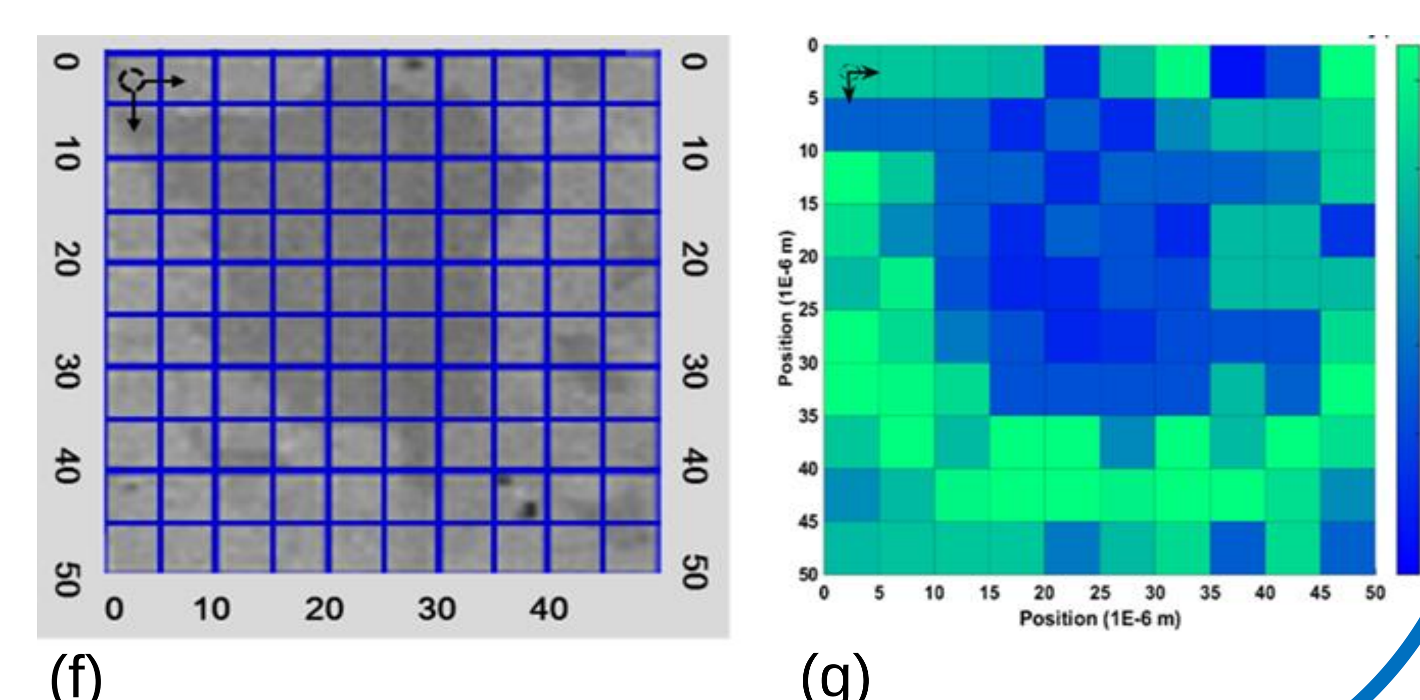


*Fig. 3.(a)350x SE image of UN/U_3Si_2 (b) EBSD phase fraction map of '(a)' (c) Phase orientation map (d) Probe laser signal for standard materials with various k (W/m*K) excited by 10 kHz pump laser (e) Experimental (blue diamond) and best-fit model (red lines) thermal response for U_3Si_2 and for UN at 20 and 50 kHz (f) SE image of vibropolished UN (light) and U_3Si_2 (dark) phases with 5 x 5 μm overlaid grid. (g)Thermal diffusivity map of '(f)' (in (10^{-6} m^2/s))*



Summary and Conclusions

- Laser based thermoreflectance techniques are an attractive option for determining local thermal transport of fresh or post-irradiated nuclear fuel
- Square-wave pulse technique validated using gold coated fused SiO_2, CaF_2, ZnSe, and ZnS standards with *k* range of 1.4 - 27.2 W/m-K; spot size of ~2 μm
- Determined local thermal diffusivity of both U_3Si_2/UN phases in a composite fuel
- Used to generate 2D-diffusivity maps of multi-phase regions of interest

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