Noninvasive Temperature Monitoring Using Change in Backscattered Energy for Clinically Relevant Heating Scenarios

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Objective of Ultrasonic Thermometry

To develop a method to produce 3D temperature maps in soft tissue during hyperthermia cancer treatment

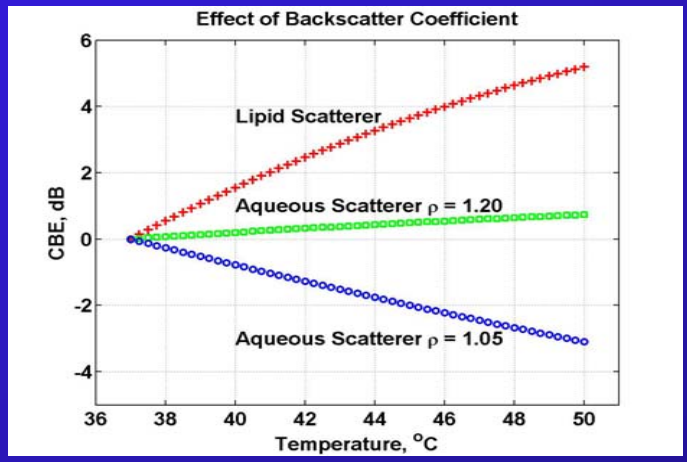
- non-invasively, conveniently at low cost with a single view from standard equipment
- with at least 0.5°C accuracy & 1 cm^3 resolution

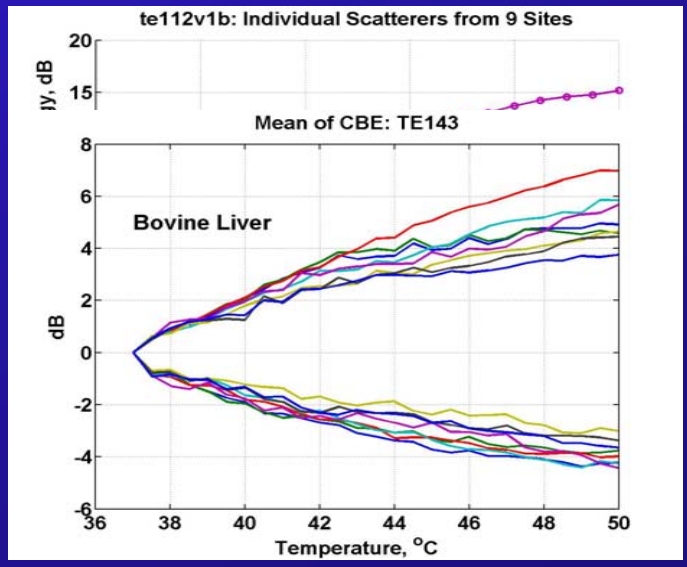
Change in backscattered energy (CBE) as a monotonic temperature-dependent parameter

CBE single-scatterer prediction
U Med & Bio, 20:915-922, 1994

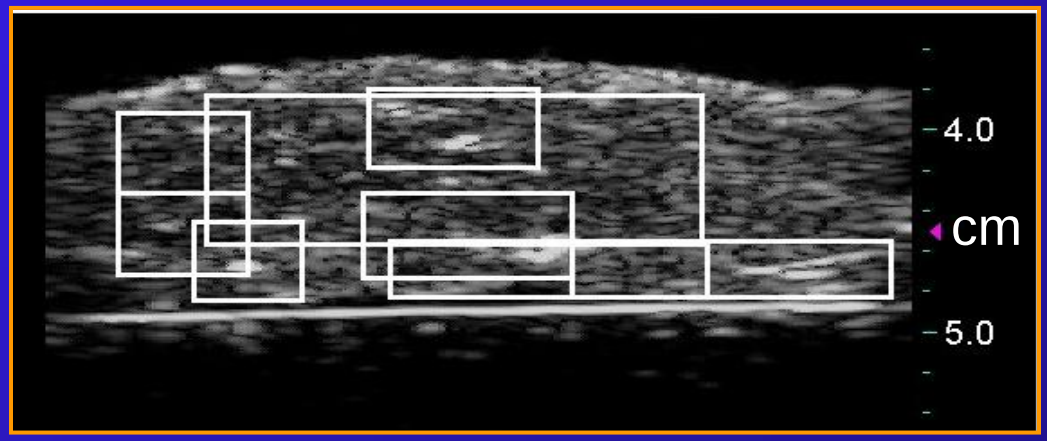
CBE from isolated echoes in 1D
Medical Physics, 30:1021-1029, 2003

CBE over selected regions in 2D
IEEE UFFC, 52:1644-1652, 2005

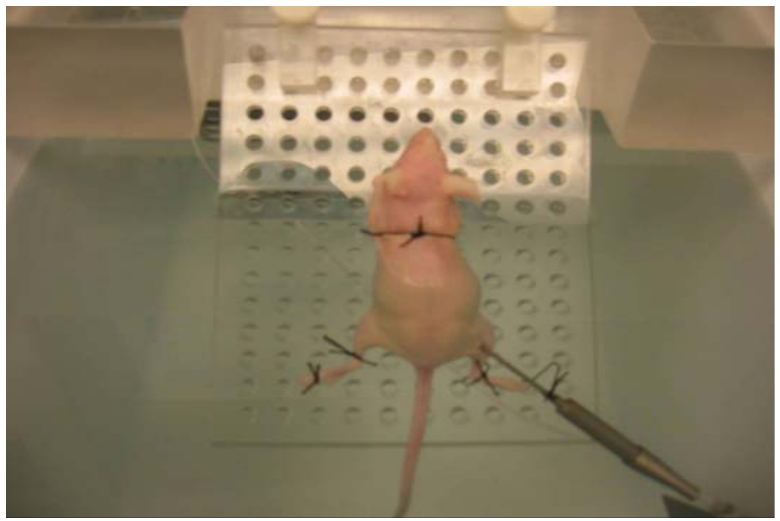


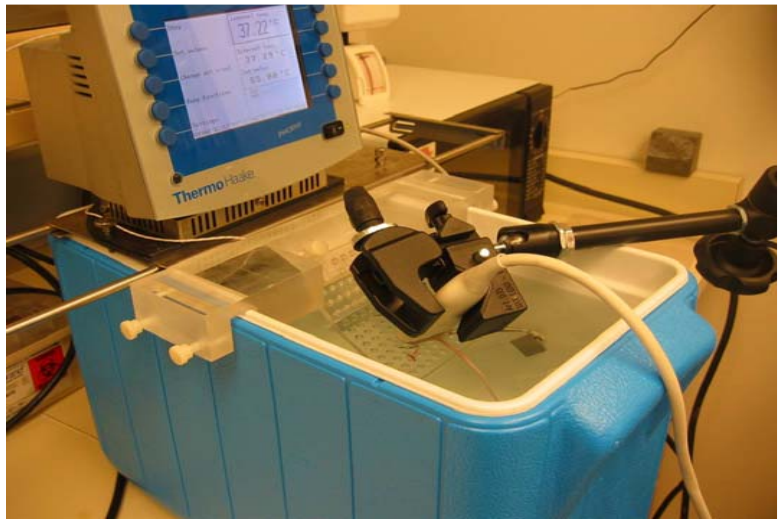


Bovine Liver

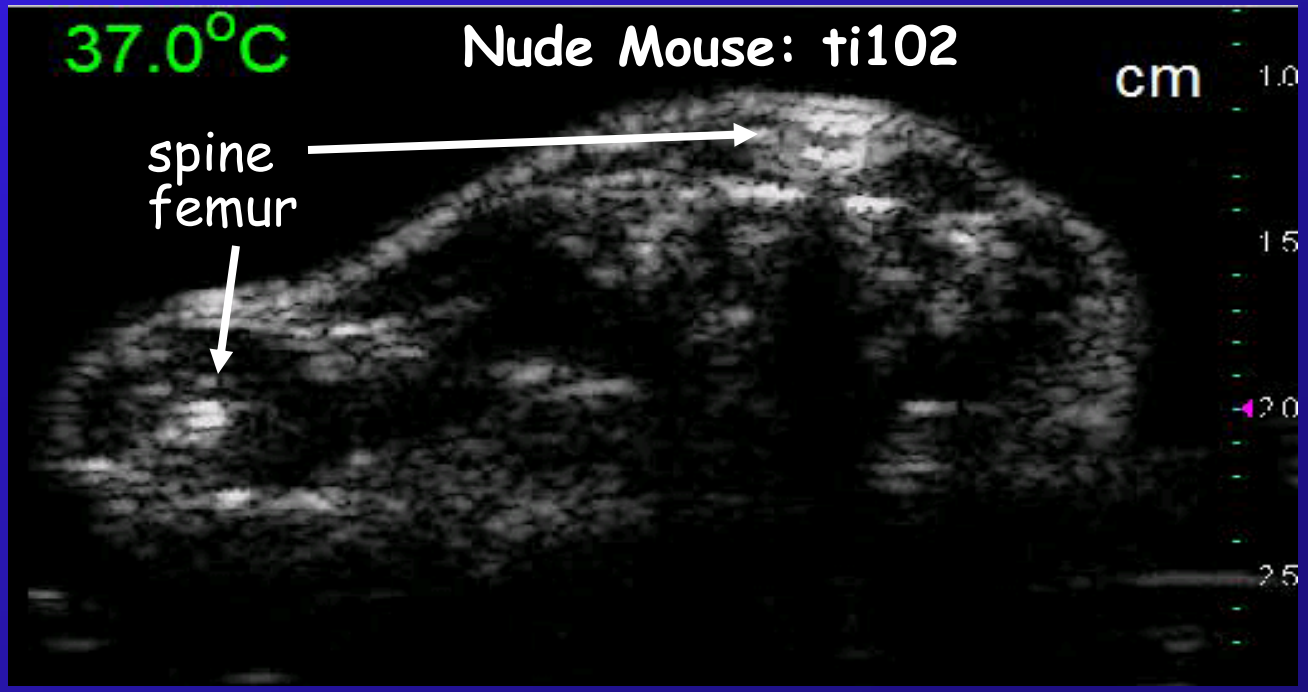


In Vivo Studies

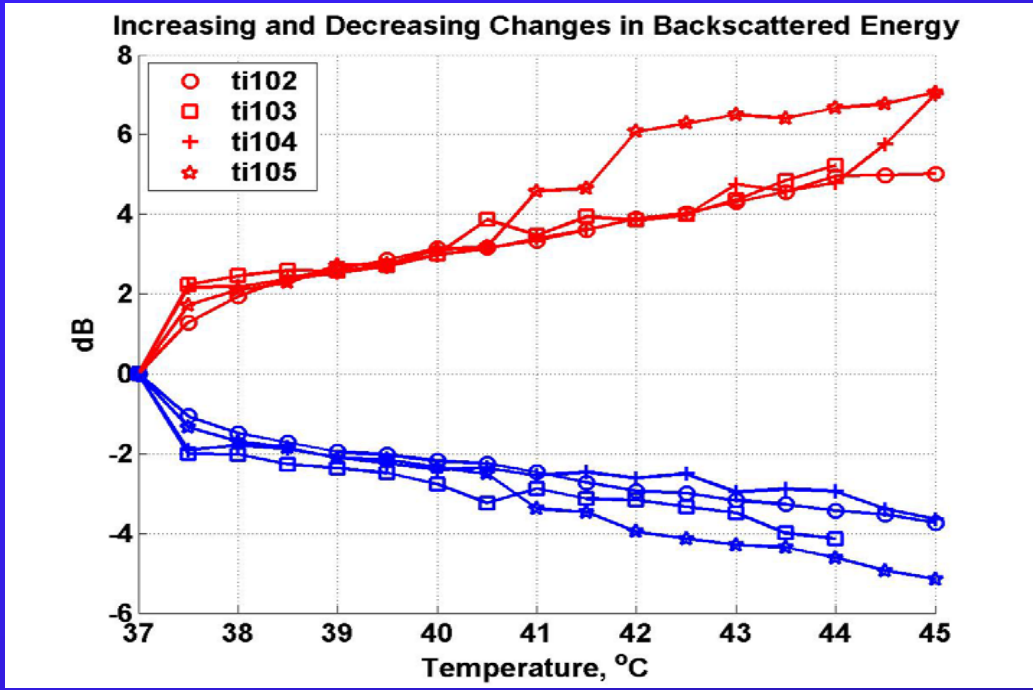


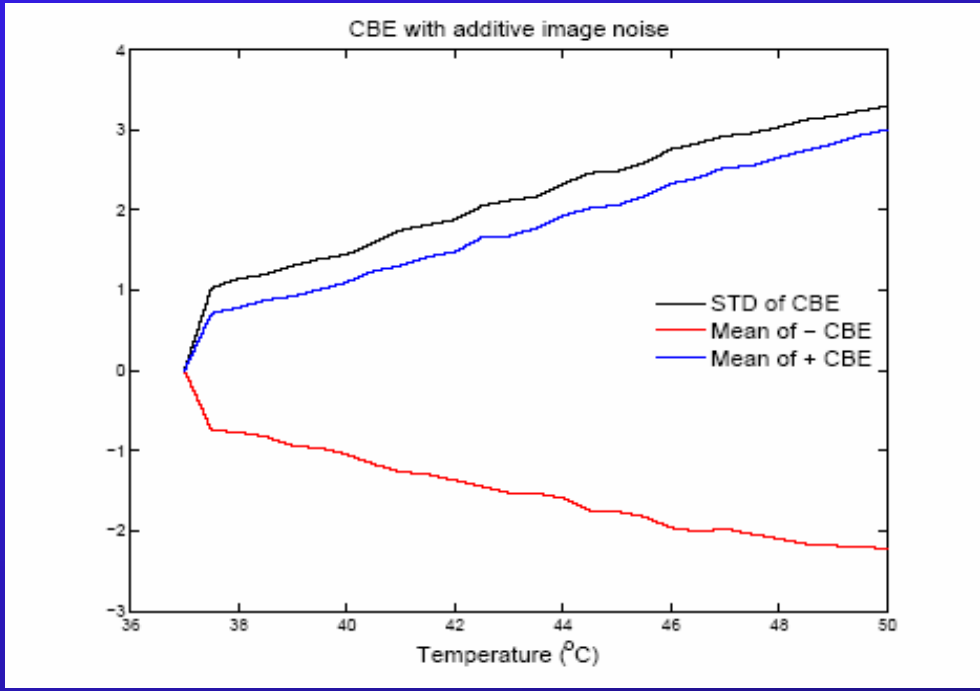


- Performed on nude mice
  - attached to submerged angled tray
  - bilaterally implanted HT29 tumors
  - RTD thermistor in contralateral tumor
- *In vitro* procedure followed
  - from 37.0 to 45.0°C in 0.5°C steps
  - for an experiment of 0.5 hours
- Mice euthanized without recovery
- Images analyzed in a manner similar to that for *in vitro* experiments



CBE with Temperature *In Vivo*

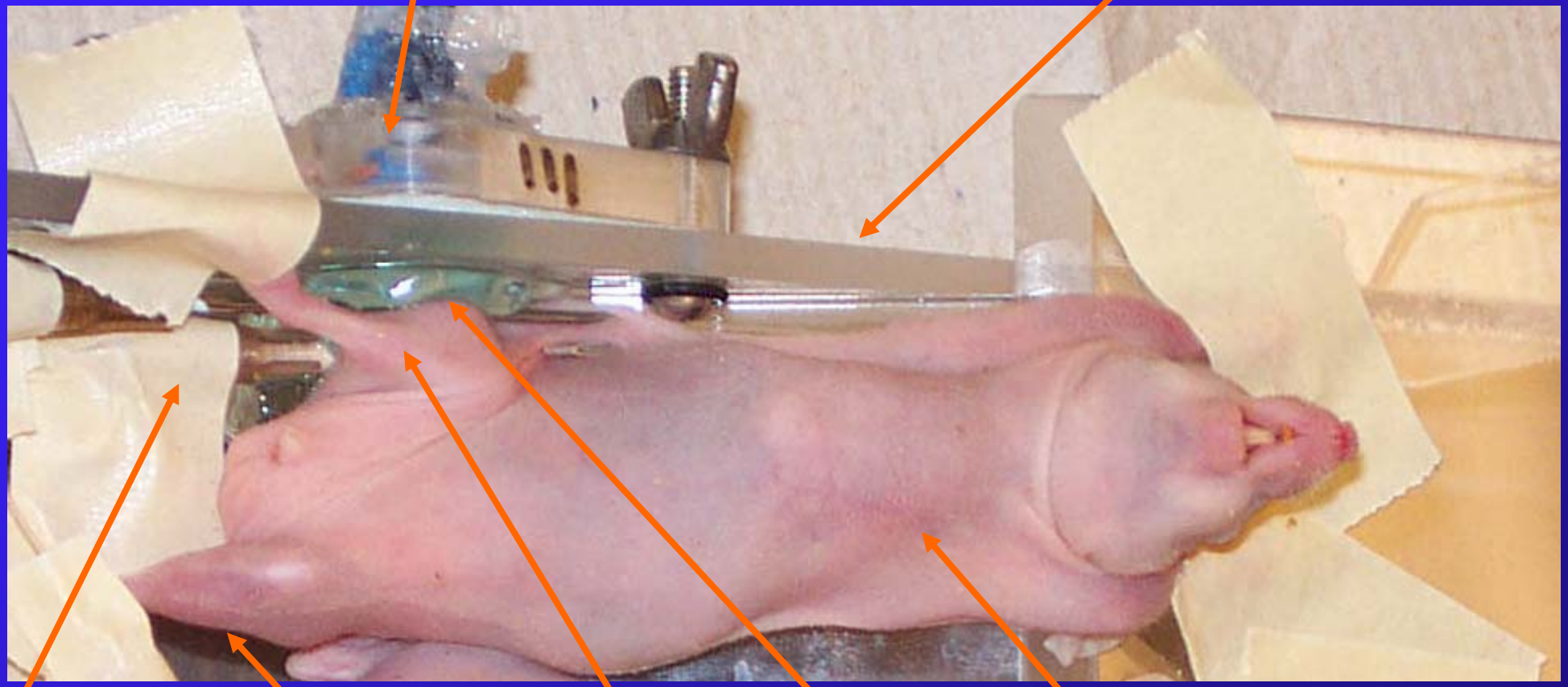




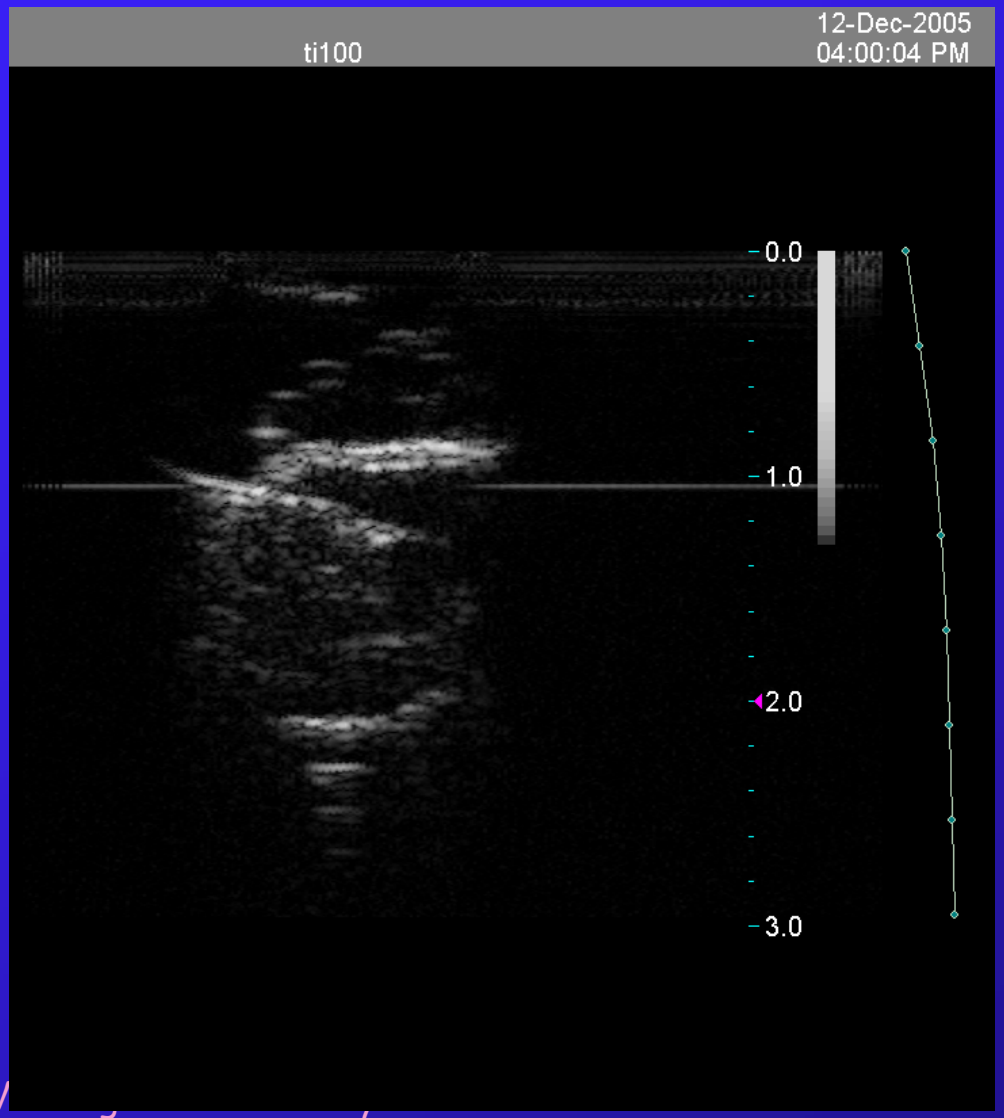
Measured CBE in mice

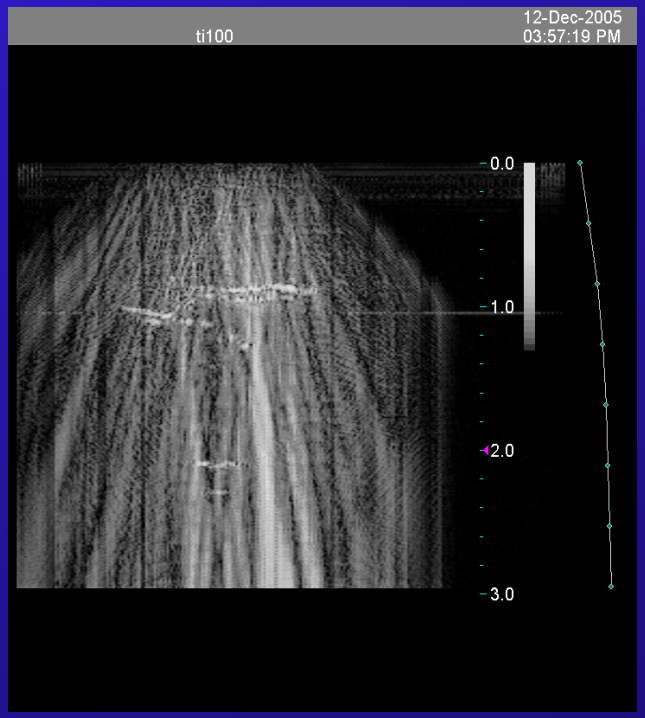
Predicted CBE in sub-wavelength scatterers

Small Animal Hyperthermia Ultrasound System

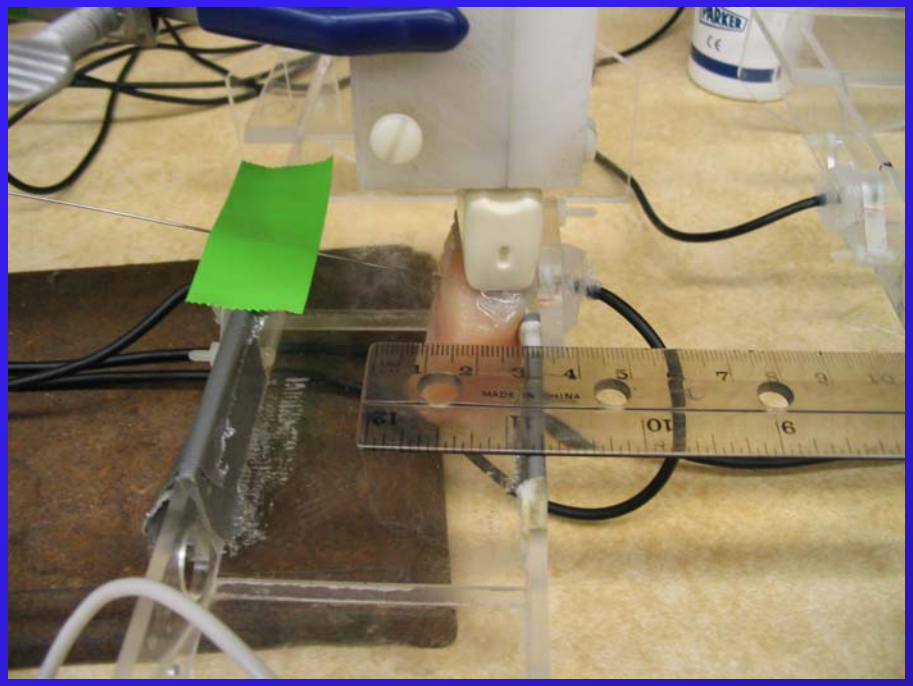


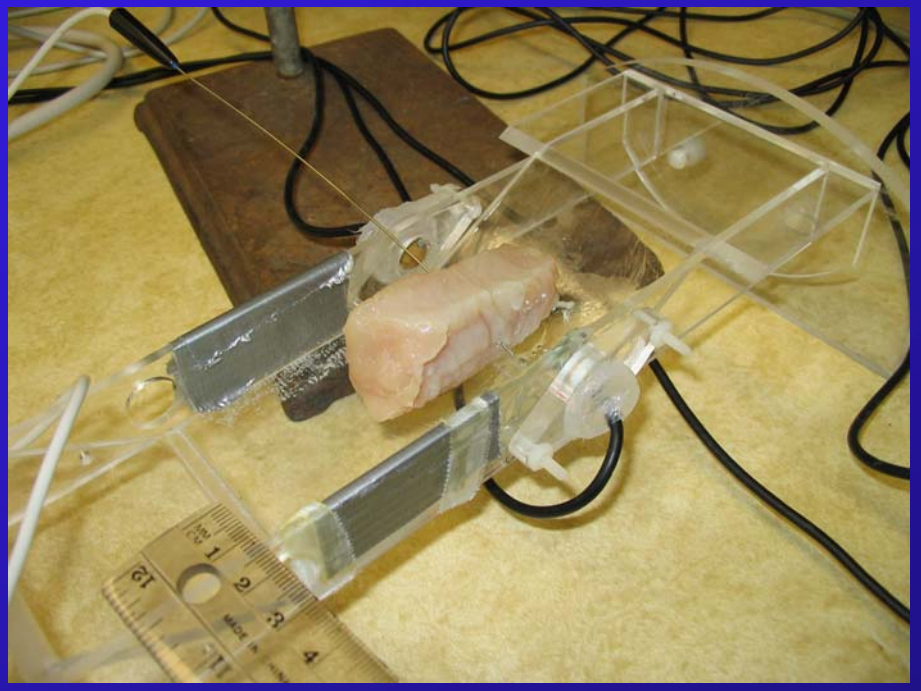
Ultrasound Images Generated by the Terson Before Ultrasound heating with the SAHUS



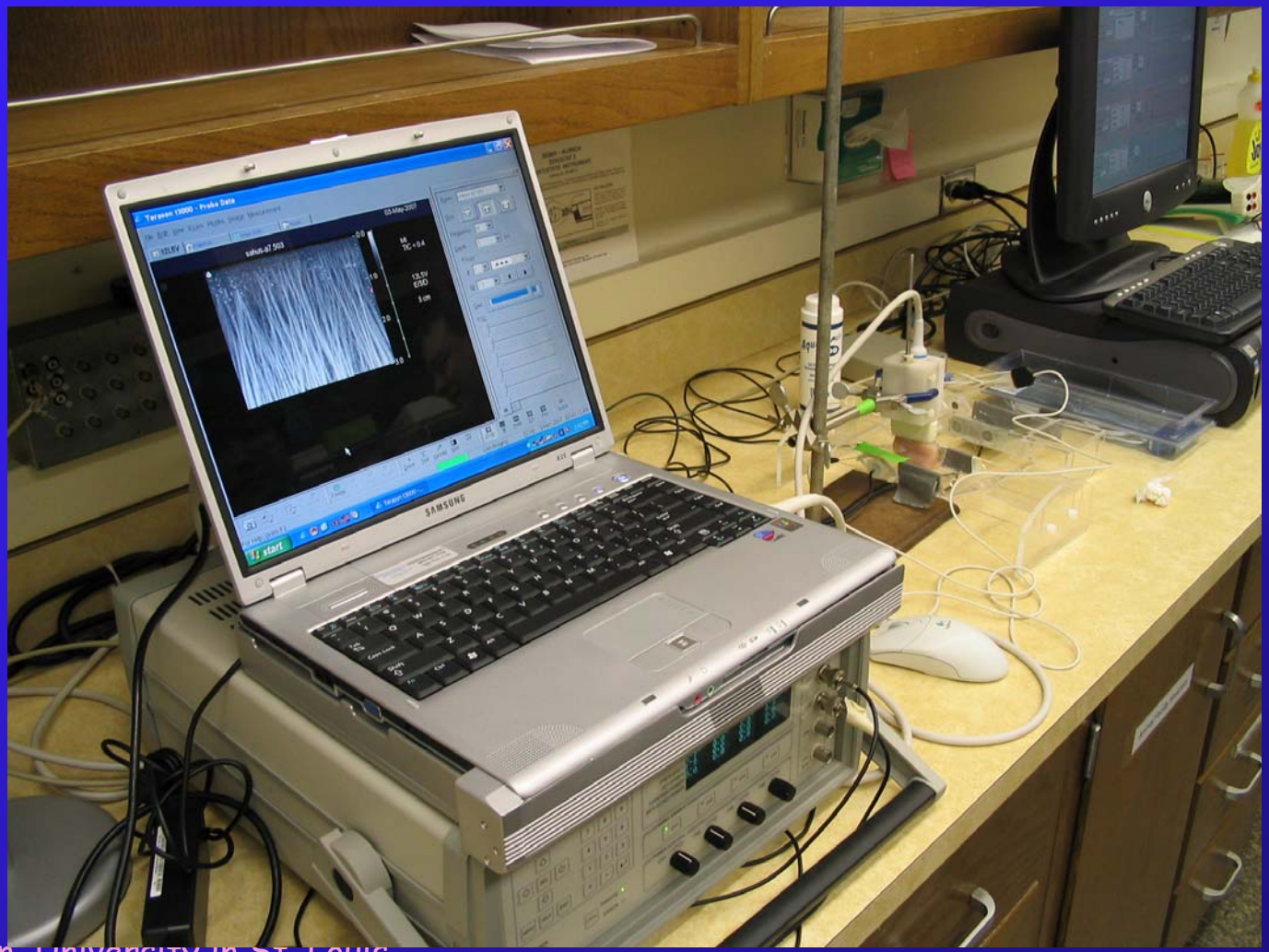


Set up for Turkey breast on SAHUS



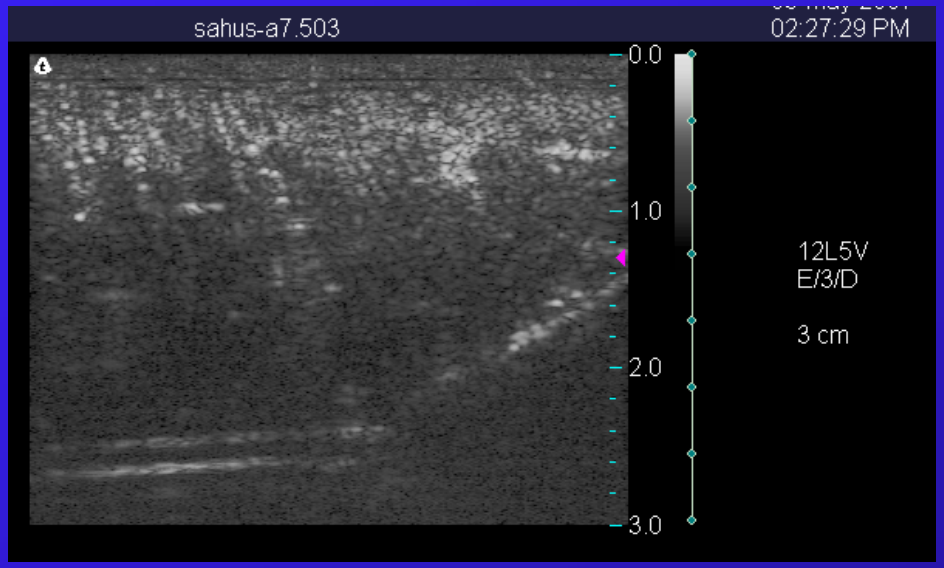


Set up for Turkey breast on SAHUS

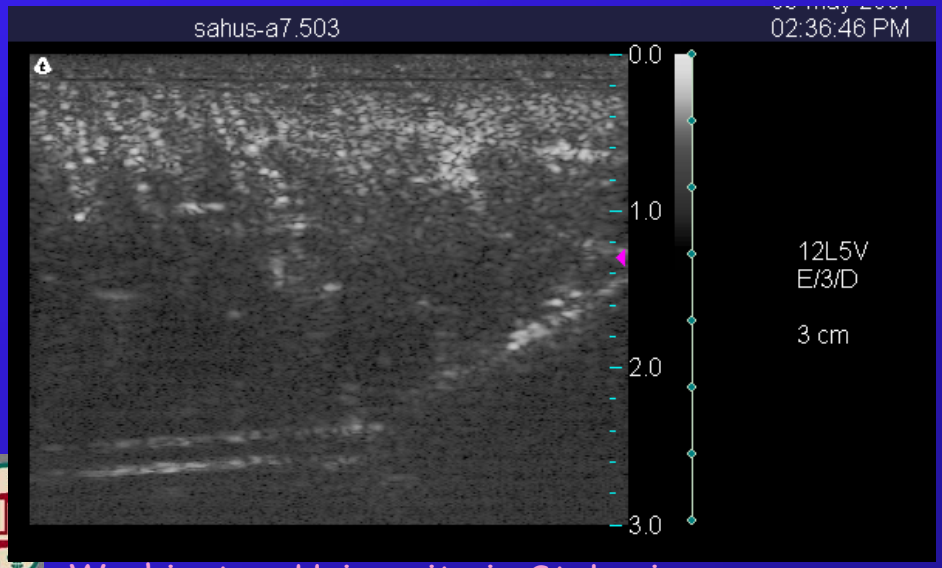


3 successive images of Turkey breast

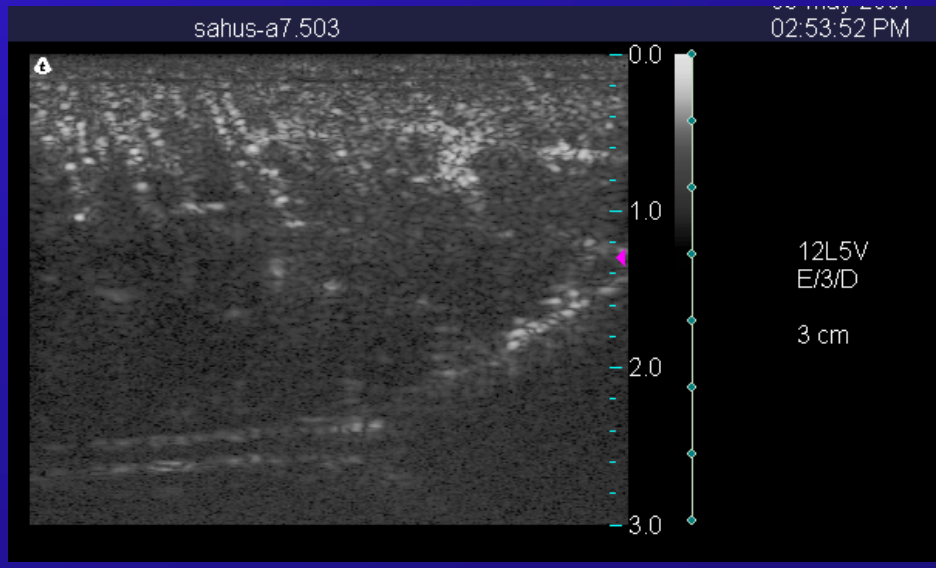
Before heating



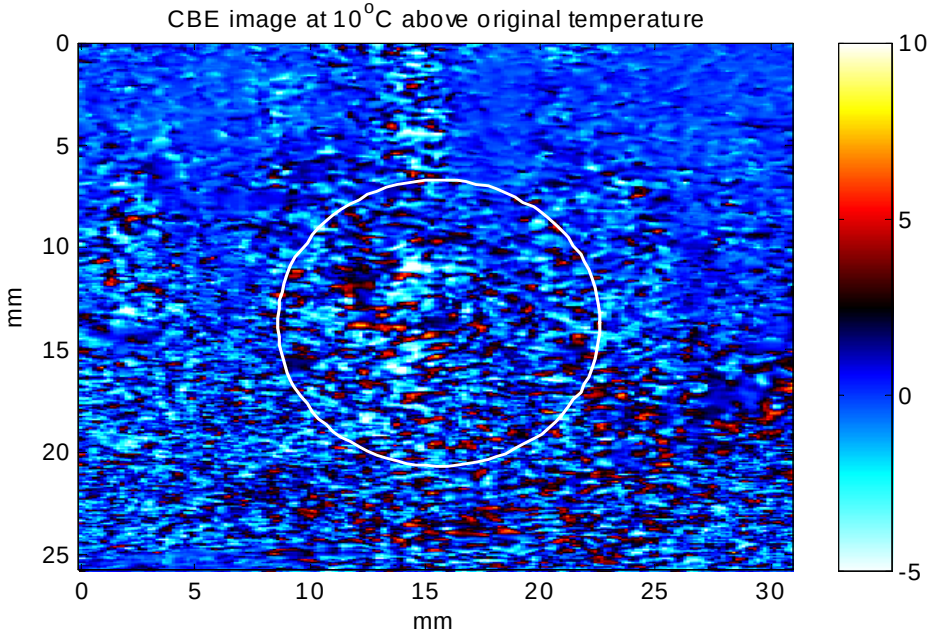
10 ºC rise

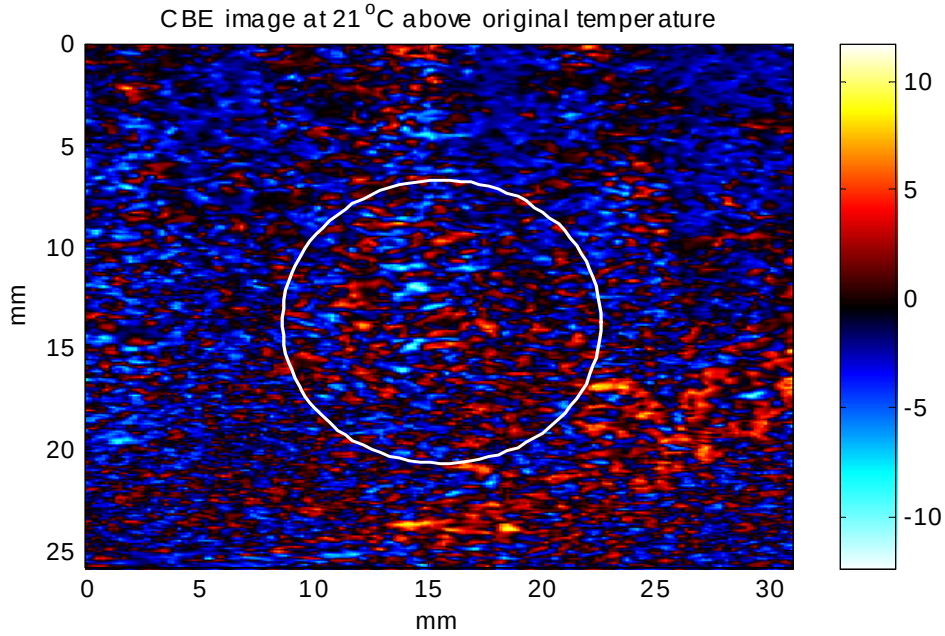


20 ºC rise

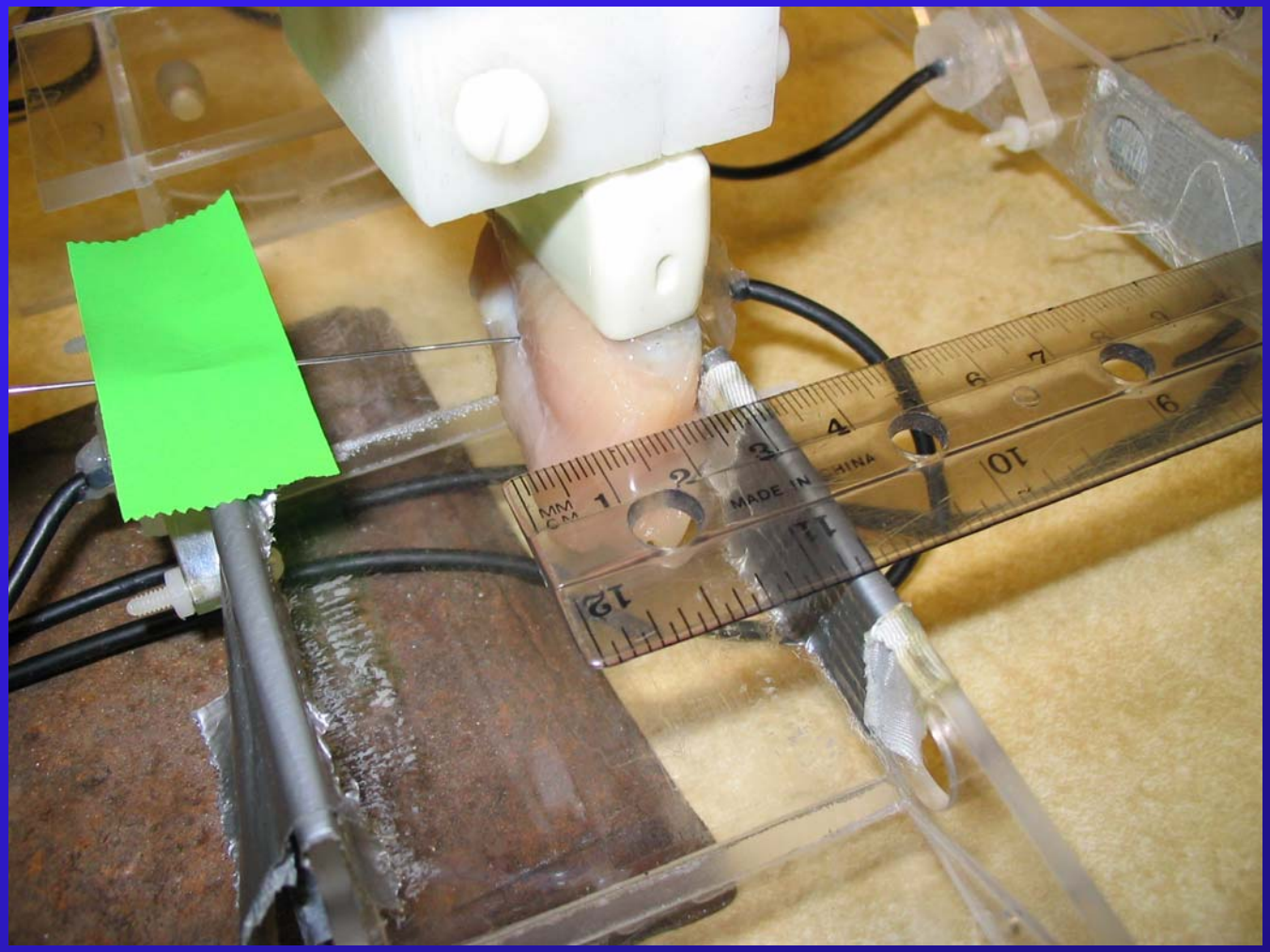


CBE images for 10 and 20 degree increase

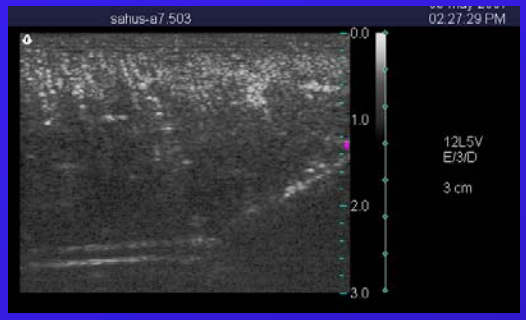


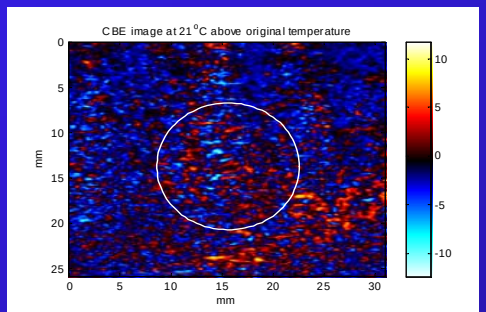


Set up for Turkey breast on SAHUS

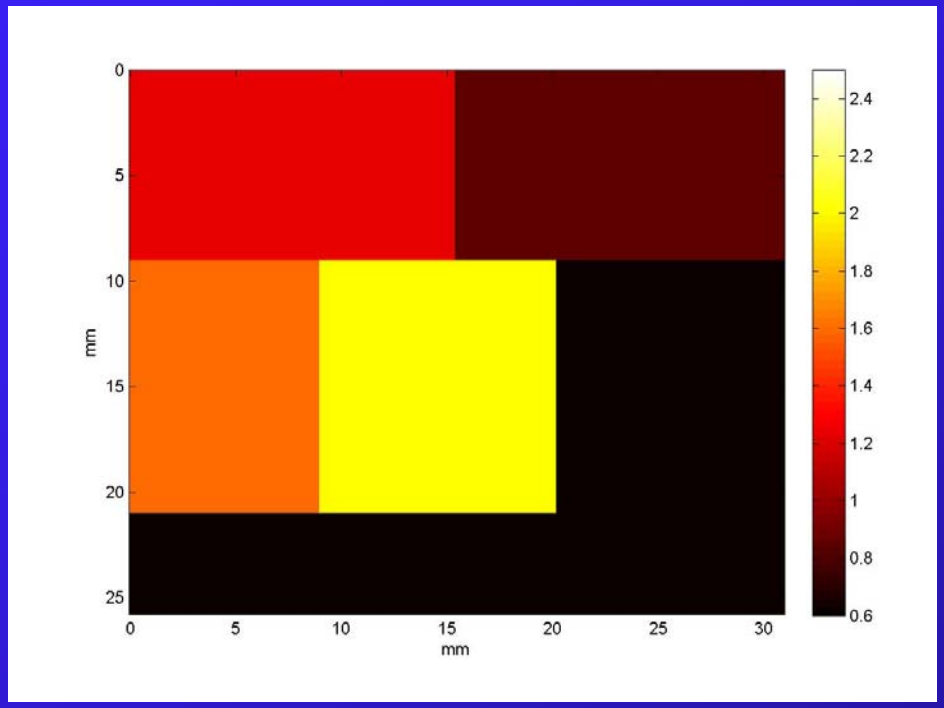


Spread of Averaged CBE

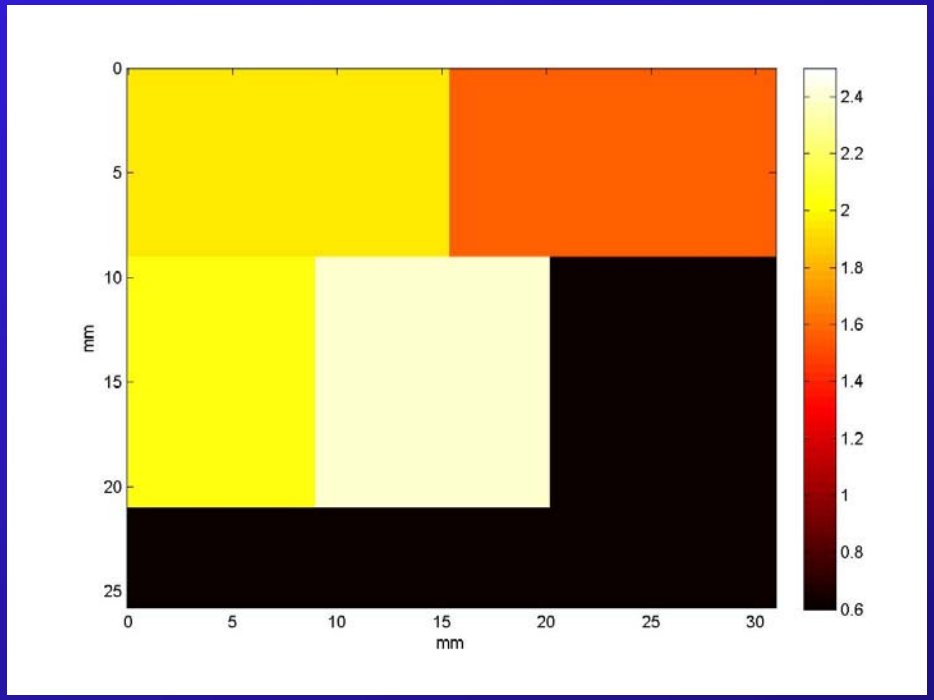




10 °C rise



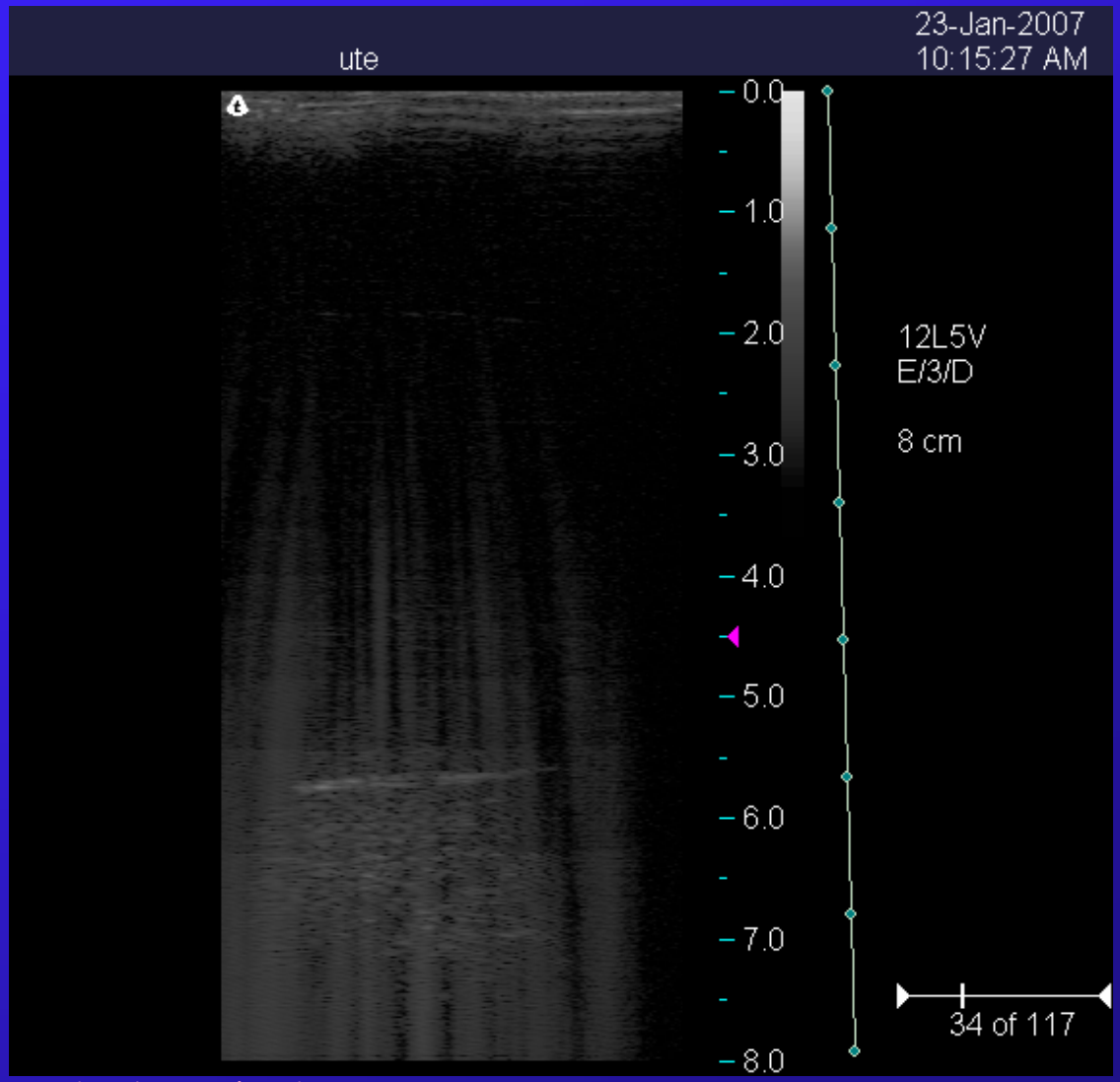
20 °C rise



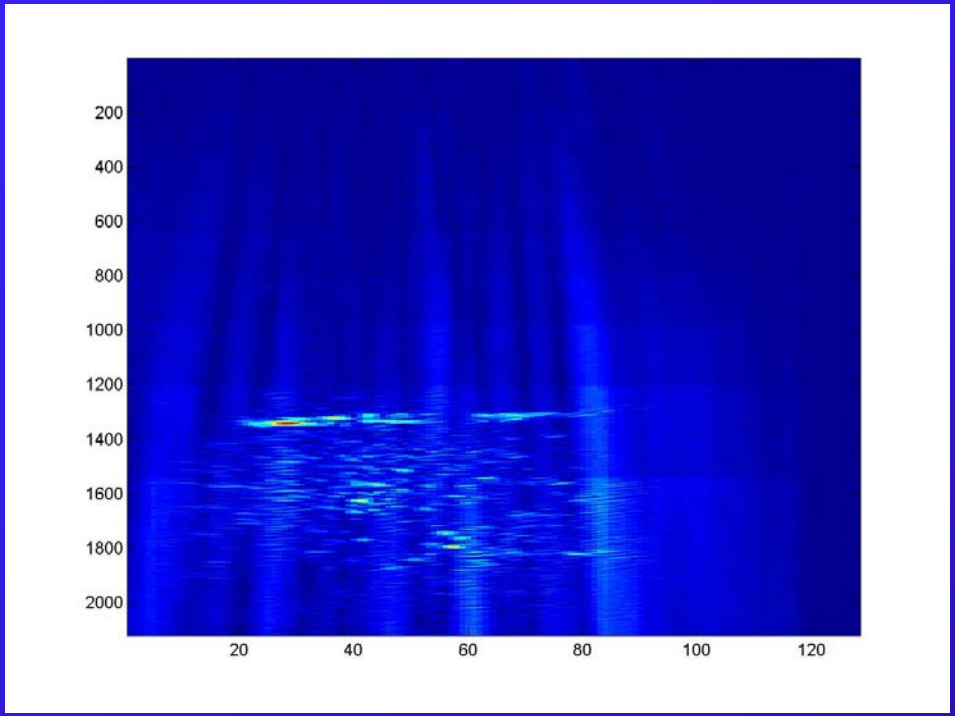
Sonotherm 1000

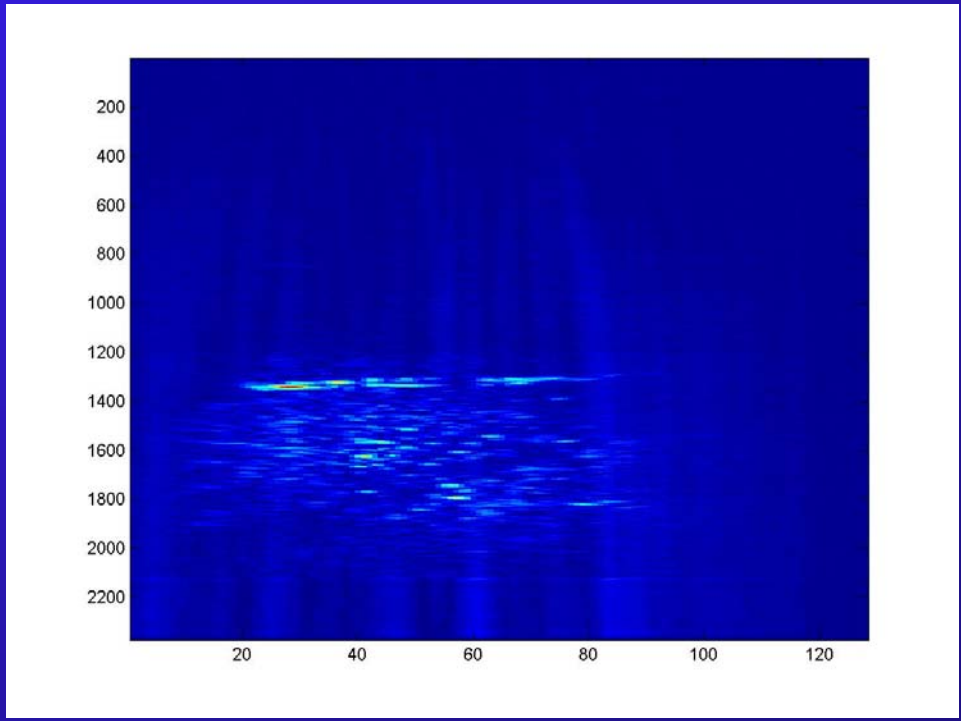
http://www.labthermics.com/

Ultrasound Image through Sonotherm Bolus

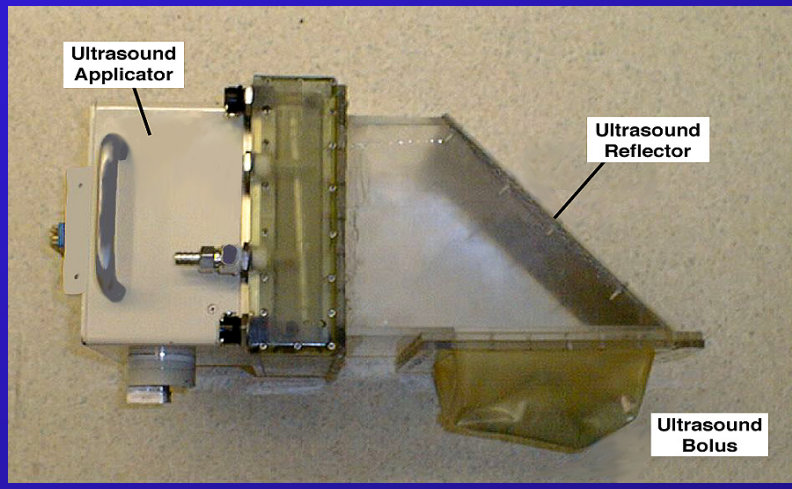


Unfiltered and filtered ultrasound image taken through the Sonotherm bolus





Ultrasound Hyperthermia



Summary & Conclusions

- Measured changes in backscattered energy (CBE) from 37 to 45°C in motion-compensated images were consistent with CBE in our model of single sub-wavelength scatterers and in simulations of collections of scatterers
- CBE varied nearly monotonically with temperature in *in vivo* mice just as it did in *in vitro* beef liver, turkey breast & pork muscle
- Measurement of CBE is possible in "Realistic heating scenarios" such as the SAHUS and perhaps with the Sonotherm

Future Directions for Thermometry Based on Ultrasonic CBE

- Better heating scenario to prove the effectiveness of CBE for identifying a heated region
  - Microwave Interstitial antenna which can effectively heat a "cylinder" of tissue
- Experimentation with Sonotherm
  - Coupling to Sonotherm heating system…
  - Completely power off Sonotherm during measurements
- True *In Vivo* testing for these heating scenarios