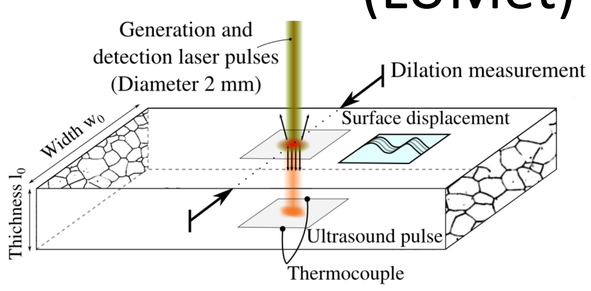
Simulation of ultrasound propagation in anisotropic polycrystalline media

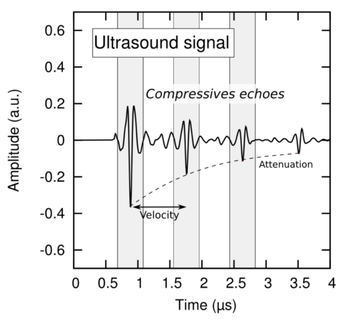
Thomas Garcin, Quentin Puydt, Warren J. Poole, Matthias Militzer

The Center for Metallurgical Process Engineering, The University of British Columbia contact: thomas.garcin@ubc.ca

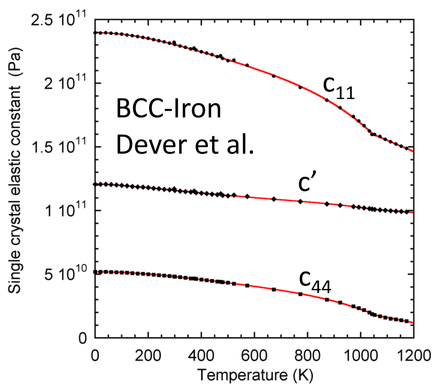
Objective: Use finite elements analysis to simulate the propagation of ultrasound wave in anisotropic polycrystalline aggregates. The simulation aims to validate experimental measurements conducted with the first commercial Laser Ultrasonics sensor (LUMet). This recent technology is dedicated to the monitoring of microstructure evolution during thermomechanical processing of metals. Ultrasound attenuation and velocity are related to metallurgical parameters such as grain size and texture and are used to examine in situ grain growth, recrystallization and phase transformation.

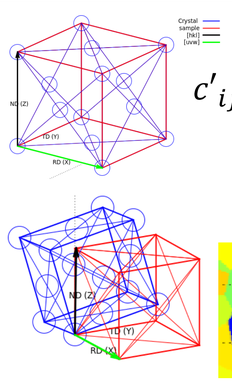
Laser Ultrasonics for Metallurgy (LUMet)





Material definition



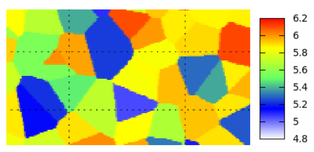


$$\sigma_{ik} = c_{ijkl}\varepsilon_{jl}$$

$$c'_{ijkl} = M_{ZYZ}c_{ijkl}\bar{M}_{ZYZ}$$

$$T_{ik}(\vec{n}) = c_{ijkl}\vec{n}_j\vec{n}_l$$

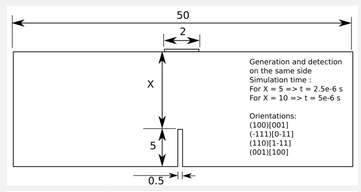
$$v_p = \sqrt{\lambda_1/\rho}$$

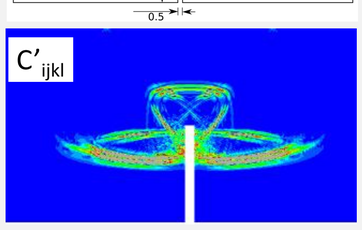


Propagation in single crystal

Sample geometry

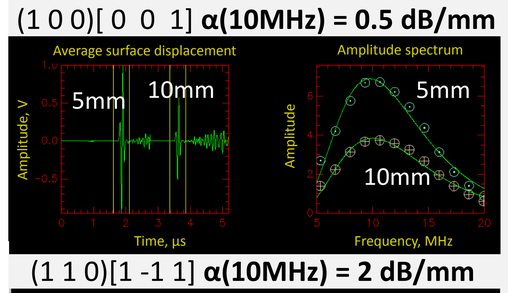
Crystal orientation
wave dispersion



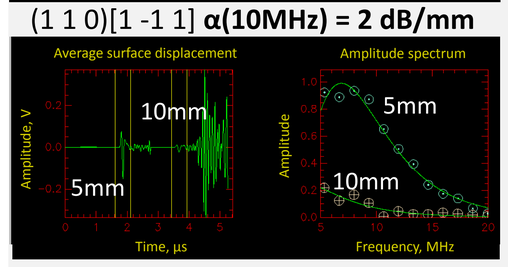


Ultrasound attenuation

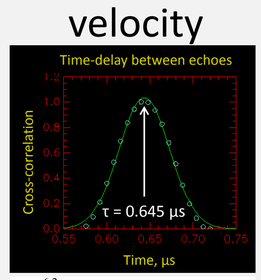
(1 0 0)[0 0 1] **α(10MHz) = 0.5 dB/mm**

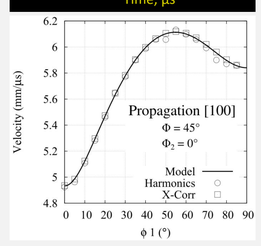


(1 1 0)[1 -1 1] **α(10MHz) = 2 dB/mm**



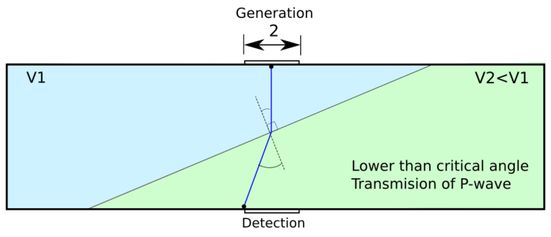
Ultrasound velocity

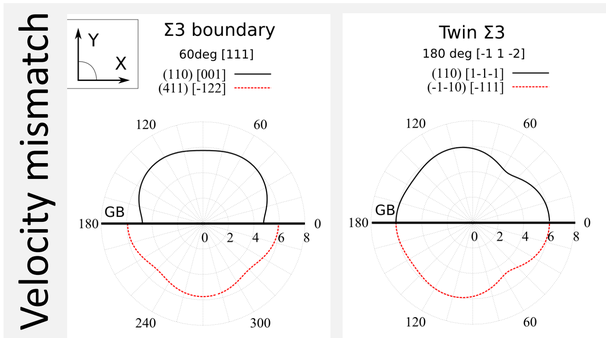




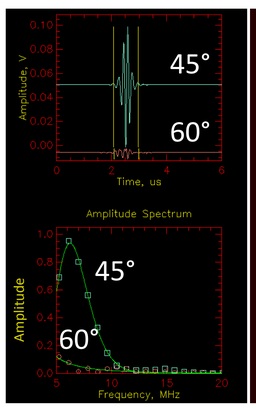
Propagation in bi-crystal

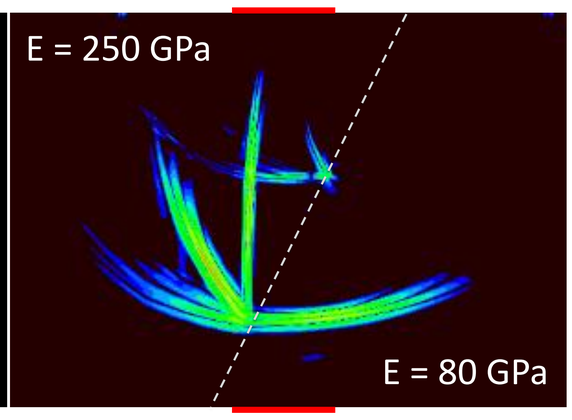
Incidence angle / Grain boundary misorientation





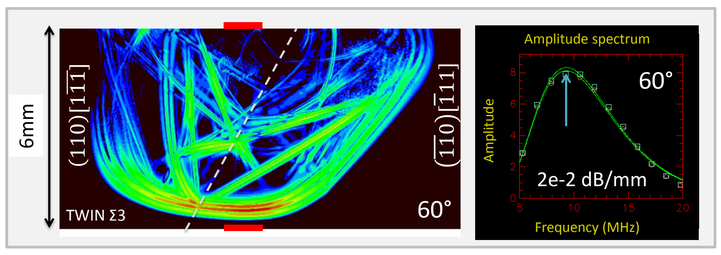
Bi-crystal , Isotropic case

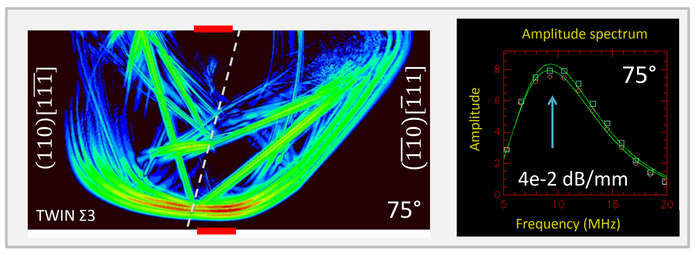




Bi-crystal , Anisotropic case

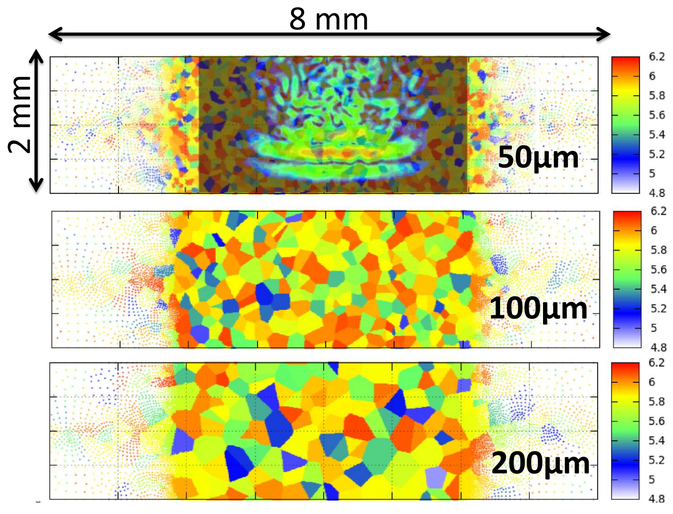
Reference : Incidence angle 45°



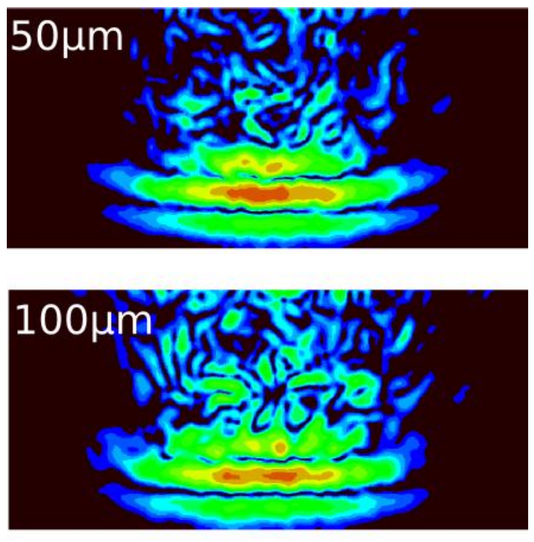


Propagation in anisotropic polycrystalline aggregate

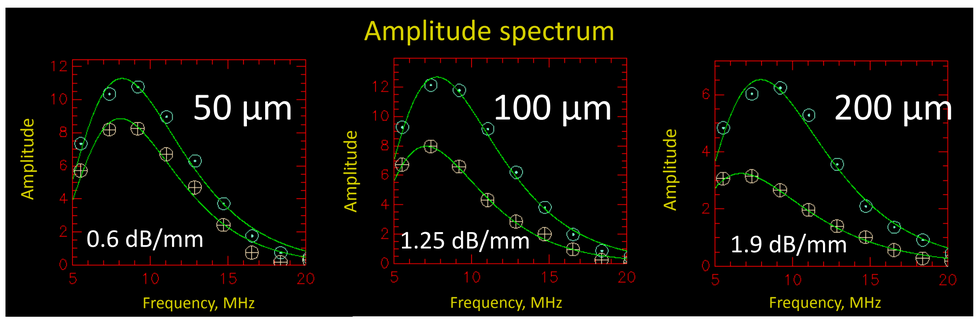
Voronoi tessellation
Attribution of crystal orientation



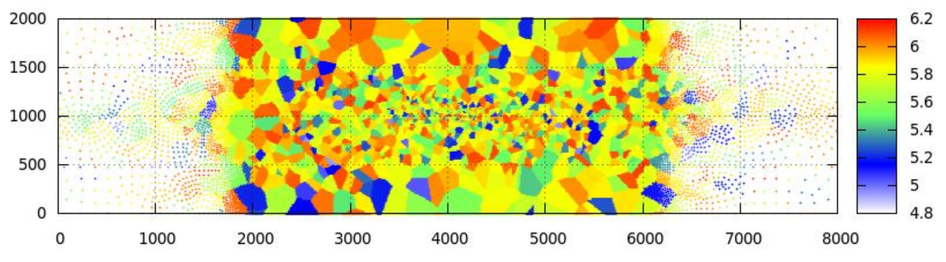
Propagation, grain scattering



Larger attenuation for larger grain size



Future work: Grain clusters with various size



Small grain size = requires finer mesh size
Large grain size = Strong effect of texture on grain scattering

Conclusion: This contribution provides an overview of our recent work on the numerical modeling of ultrasonic wave propagation in anisotropic polycrystalline aggregate using the finite element analysis. The simulation tools is perfectly suitable to examine complex wave propagation phenomena such grain boundary scattering and the effect of preferred orientation on the measured ultrasound parameters.

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