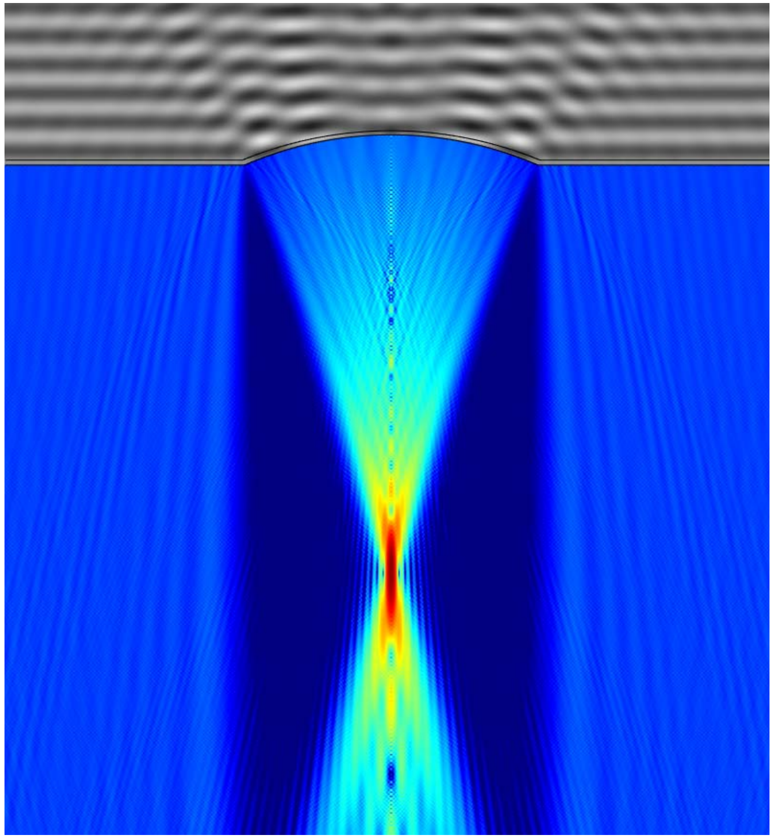
Multiphysics Simulation of a High Frequency Acoustic Microscope Lens



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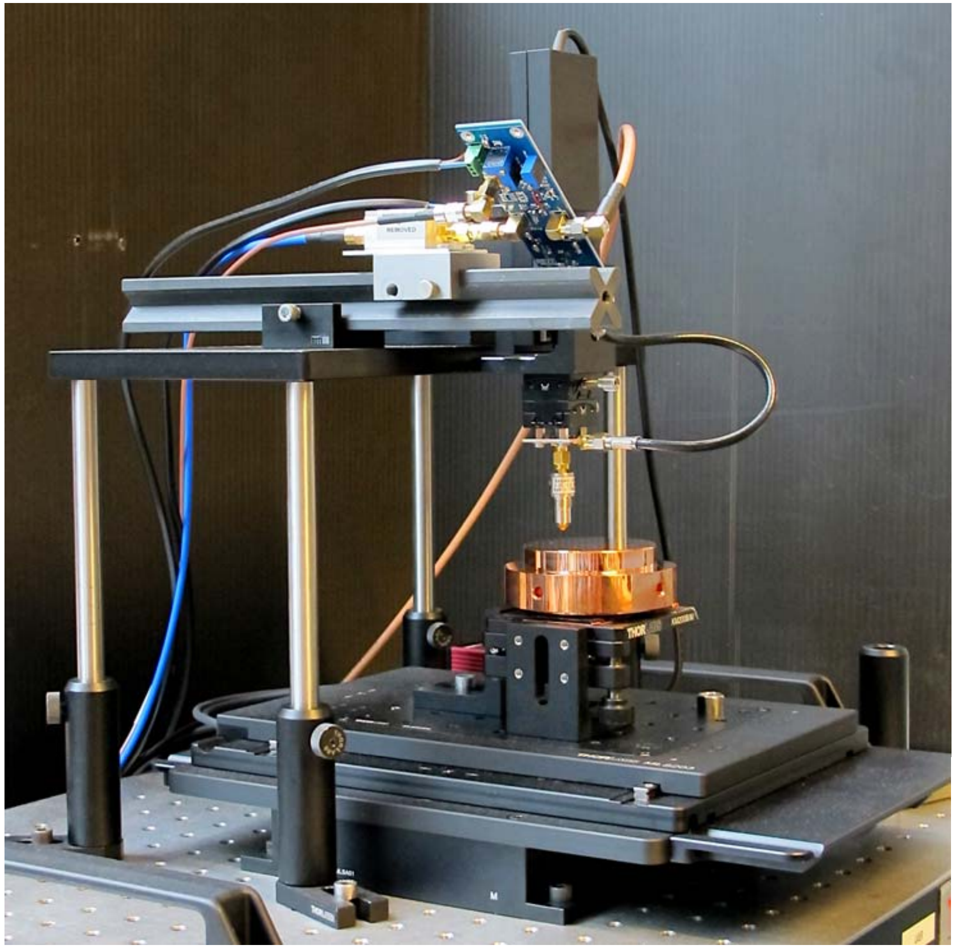
Introduction

- Scanning acoustic microscope (SAM)
  - Performs a point scan using a focused ultrasound pulse



Introduction

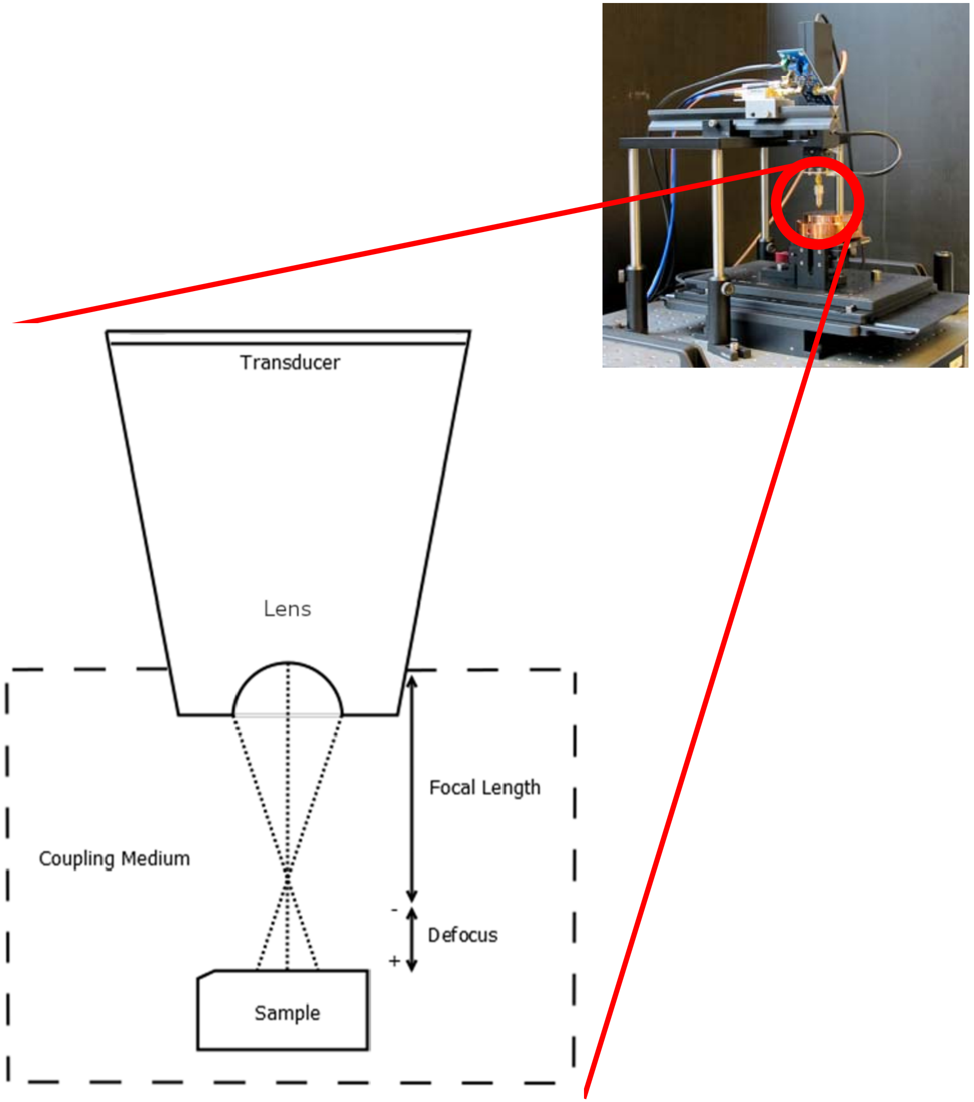
- Scanning acoustic microscope (SAM)
  - Performs a point scan using a focused ultrasound pulse

- Focused ultrasound reflects off the object
  - Amplitude
  - Time of flight

Introduction

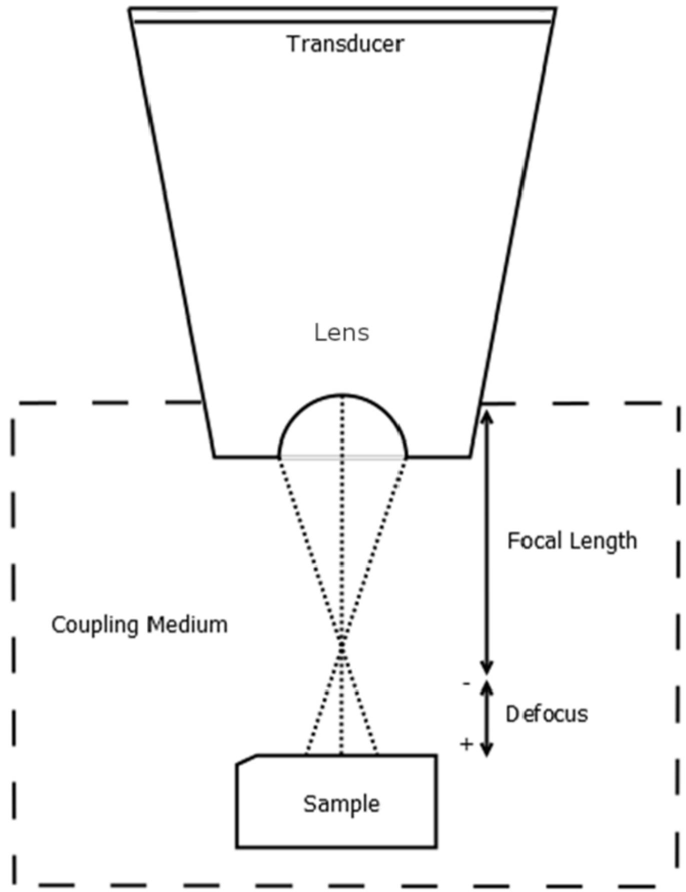
- SAM transducer-lens system
    - Transducer (piezo)
    - Lens with spherical surface (sapphire)
    - Anti-reflection coating (glass)
    - Coupling medium (water)

- Spherical lens surface focuses acoustic waves
    - Focal length depends on the shape of the lens



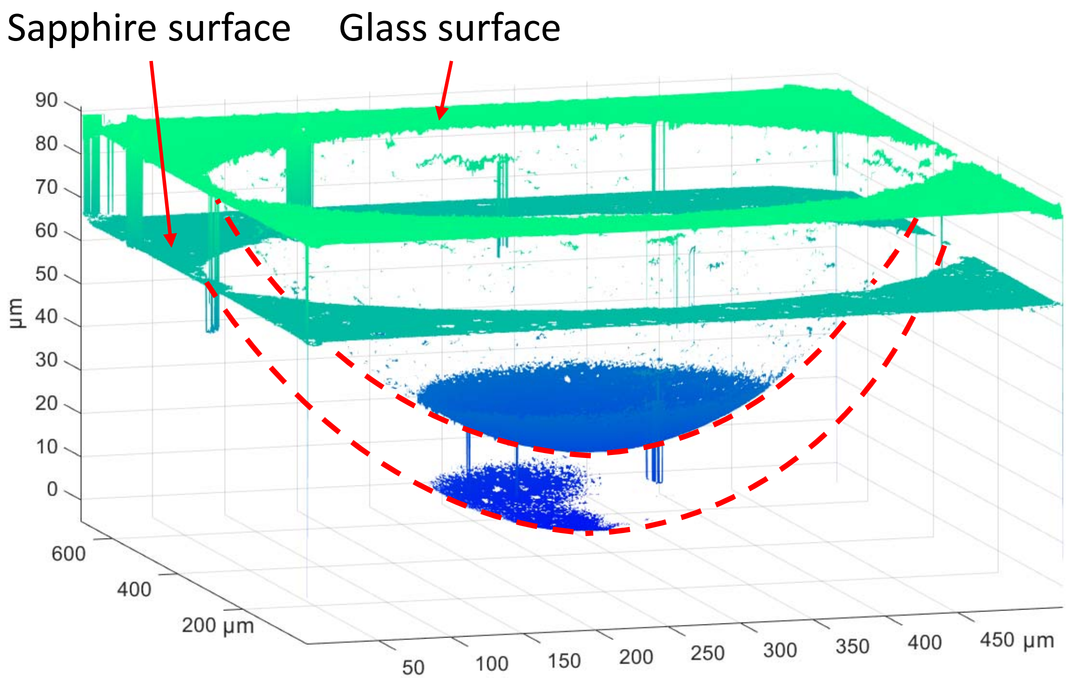
Motivation

- SAM uses broadband signal
  - Central frequency 250 MHz
  - Consists of frequencies in range of 130 – 370 MHz
- Is focal length same at every frequency?
  - If not, might lead to loss of information
  - Hard to study experimentally



Simulation geometry

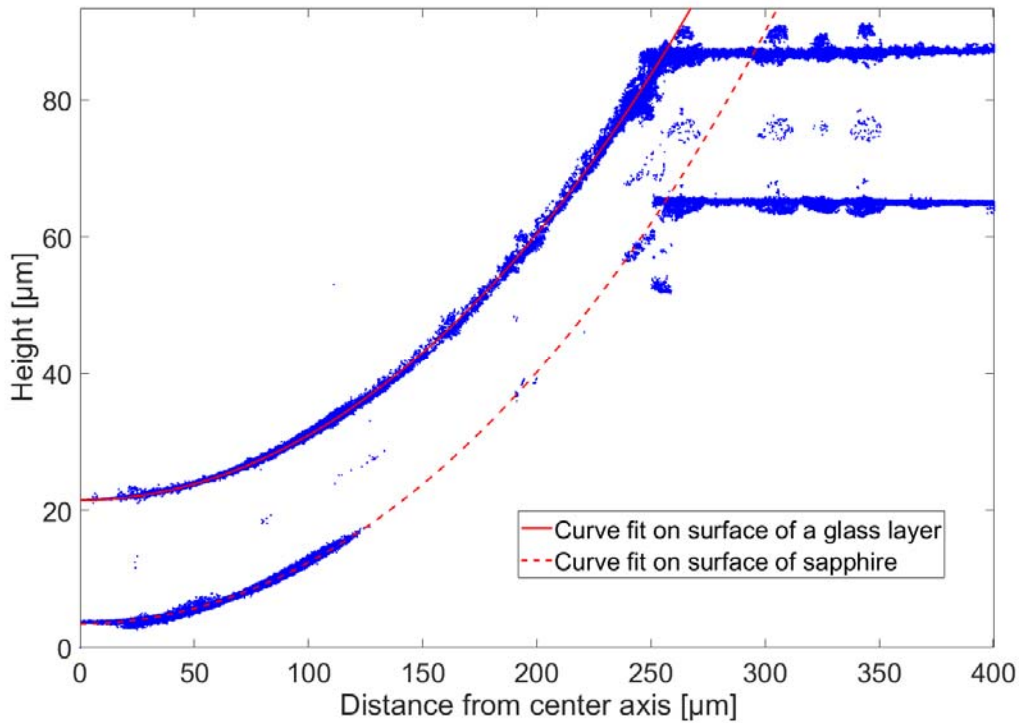
- Acoustic lens shape
  - Imaged using scanning white light interferometric 3D microscope



Simulation geometry

- Acoustic lens shape
  - Imaged using scanning white light interferometric 3D microscope

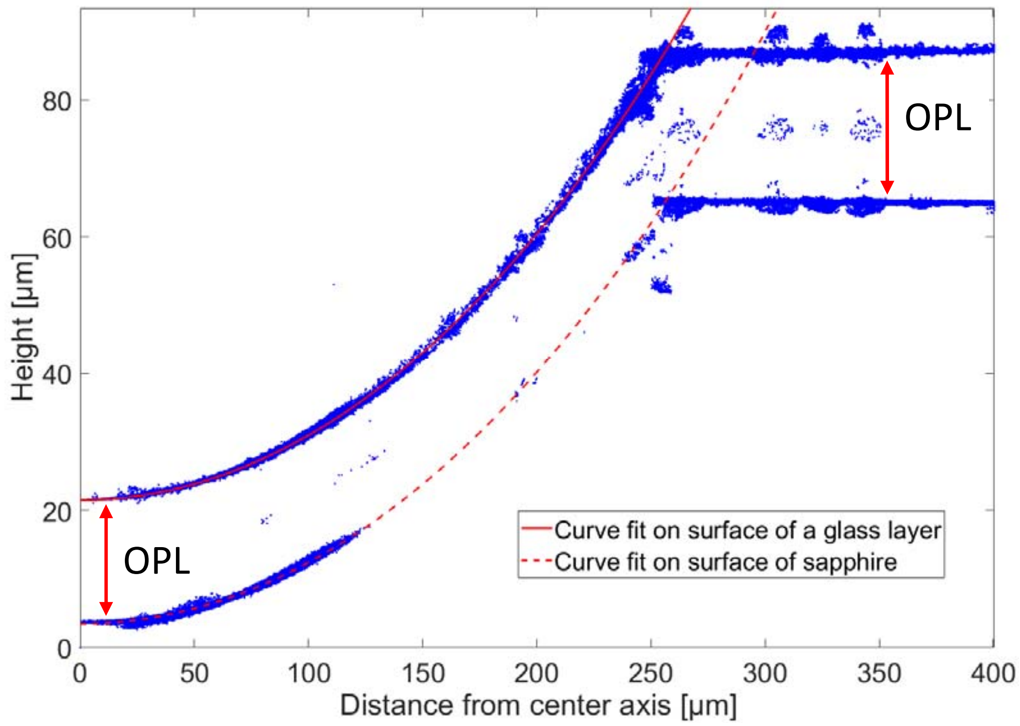
- Lens surface profile
  - 3D image rotated around its central axis



Simulation geometry

- Acoustic lens shape
  - Imaged using scanning white light interferometric 3D microscope
- Lens surface profile
  - 3D image rotated around its central axis
- Thickness of anti-reflection coating
  - $d = \frac{OPL}{2\,n}$ ≈ 5.84 µm (bottom)

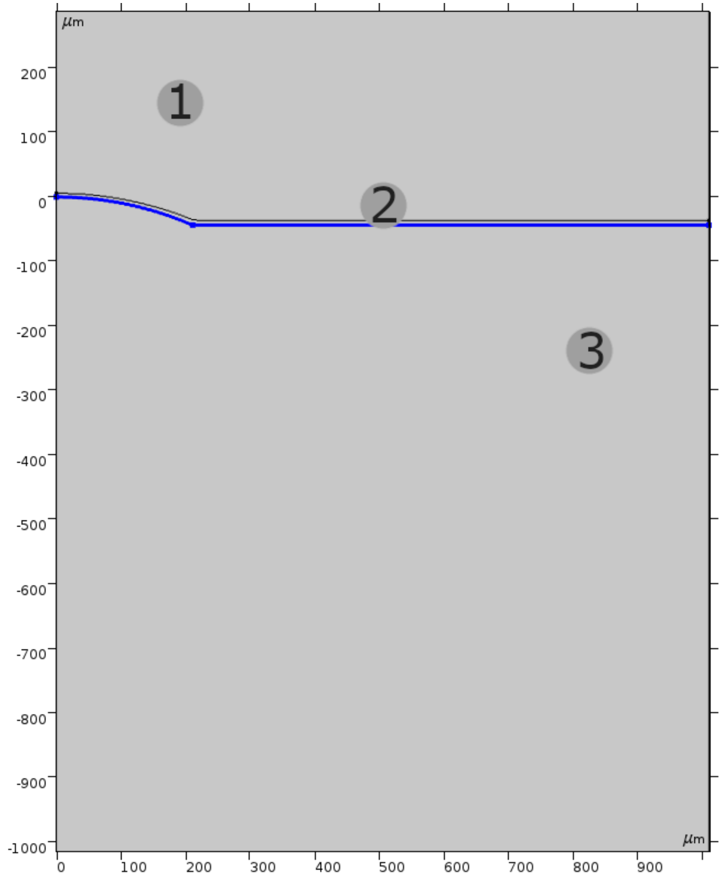
    ≈ 7.07 µm (top)



Simulation geometry

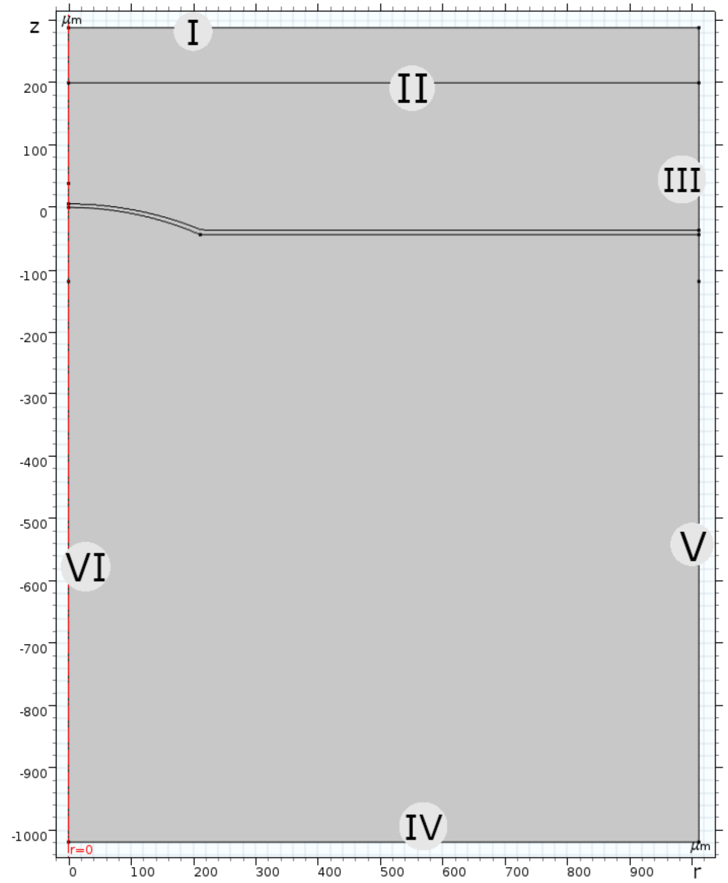
- 2D axisymmetric geometry constructed in COMSOL Multiphysics®

- Three material domains
  1. Sapphire
  2. Soda-lime glass
  3. Water
- Physics:
  - Solid Mechanics
  - Pressure Acoustic
- Acoustic-Structure interaction coupling



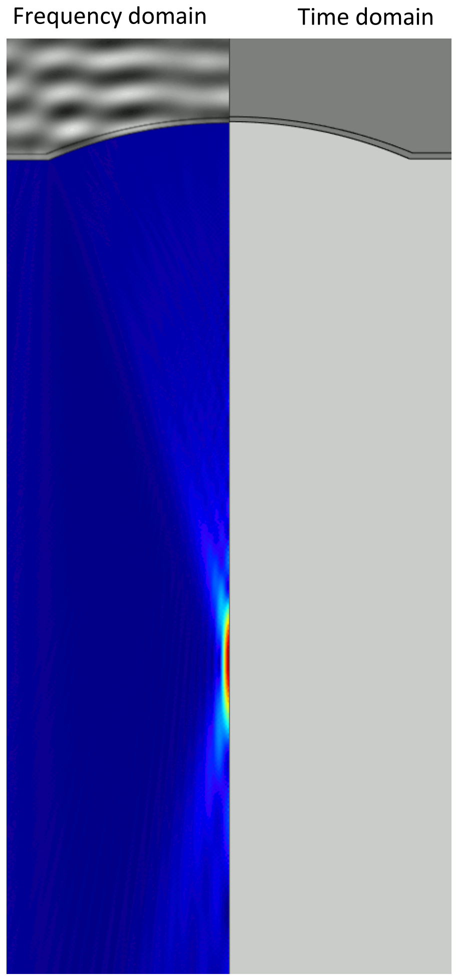
Simulation geometry

- Boundary conditions:
  I. Low-reflecting boundary
  II. Boundary load
  III. Roller
  IV. Plane wave radiation
  V. Sound hard boundary
  VI. Axial symmetry



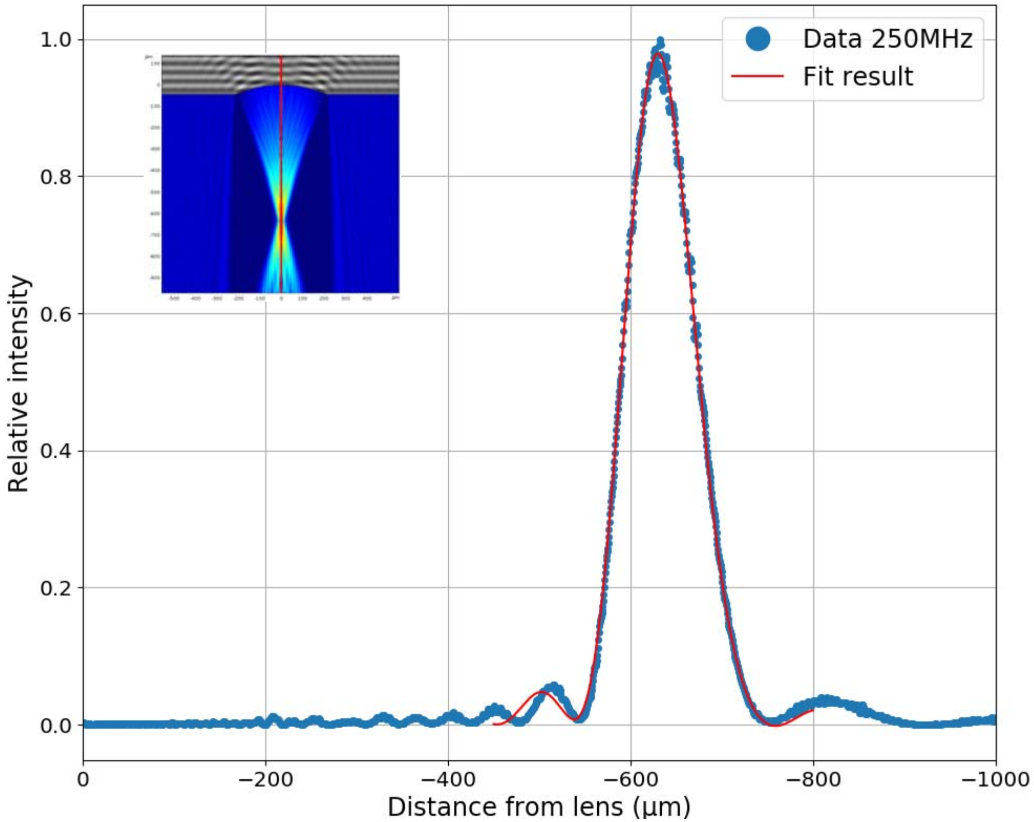
Simulation

- Frequency domain simulation
  - Computationally more efficient
  - Sweep frequencies 100 – 400 MHz with step of 0.5 MHz
- Time domain simulation
  - Comparison with frequency domain results
  - Two sweeps:
    1. Frequencies 100 – 400 MHz with step of 25 MHz
    2. Frequencies 100 – 200 MHz with step of 10 MHz



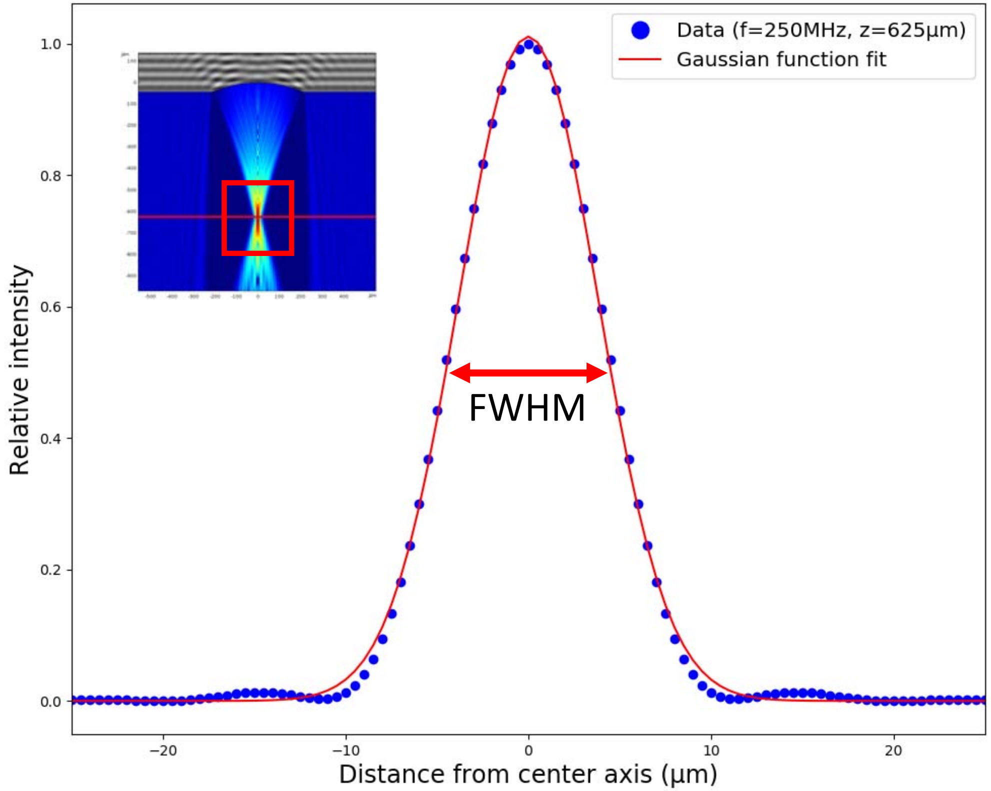
Analysis of results

- 1D line data set along z-axis
  - Determining the location of intensity peak
  - Wave interference visible in frequency domain results
    - Curve fit to smooth frequency domain results



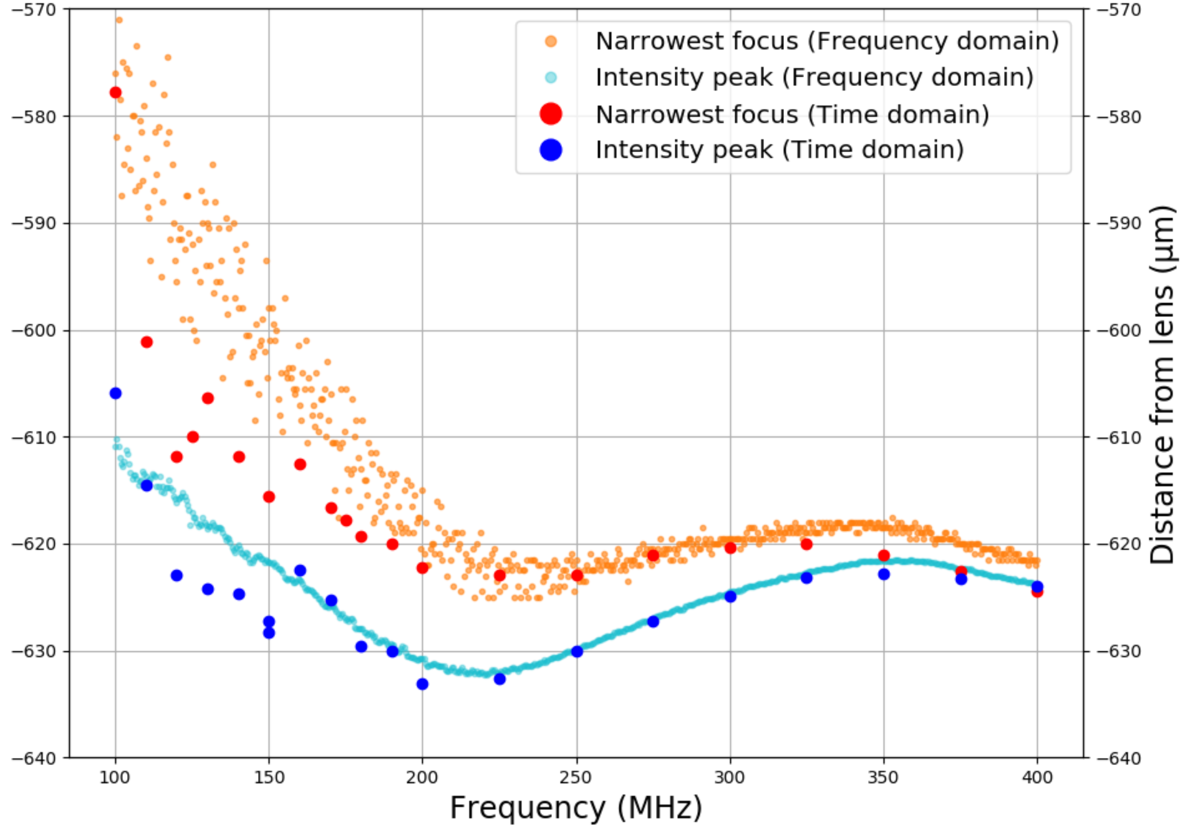
Analysis of results

- 2D grid data set near expected focus point
  - Gaussian fit to each horizontal line within set
  - Full width at half maximum (FWHM) of each fit defined



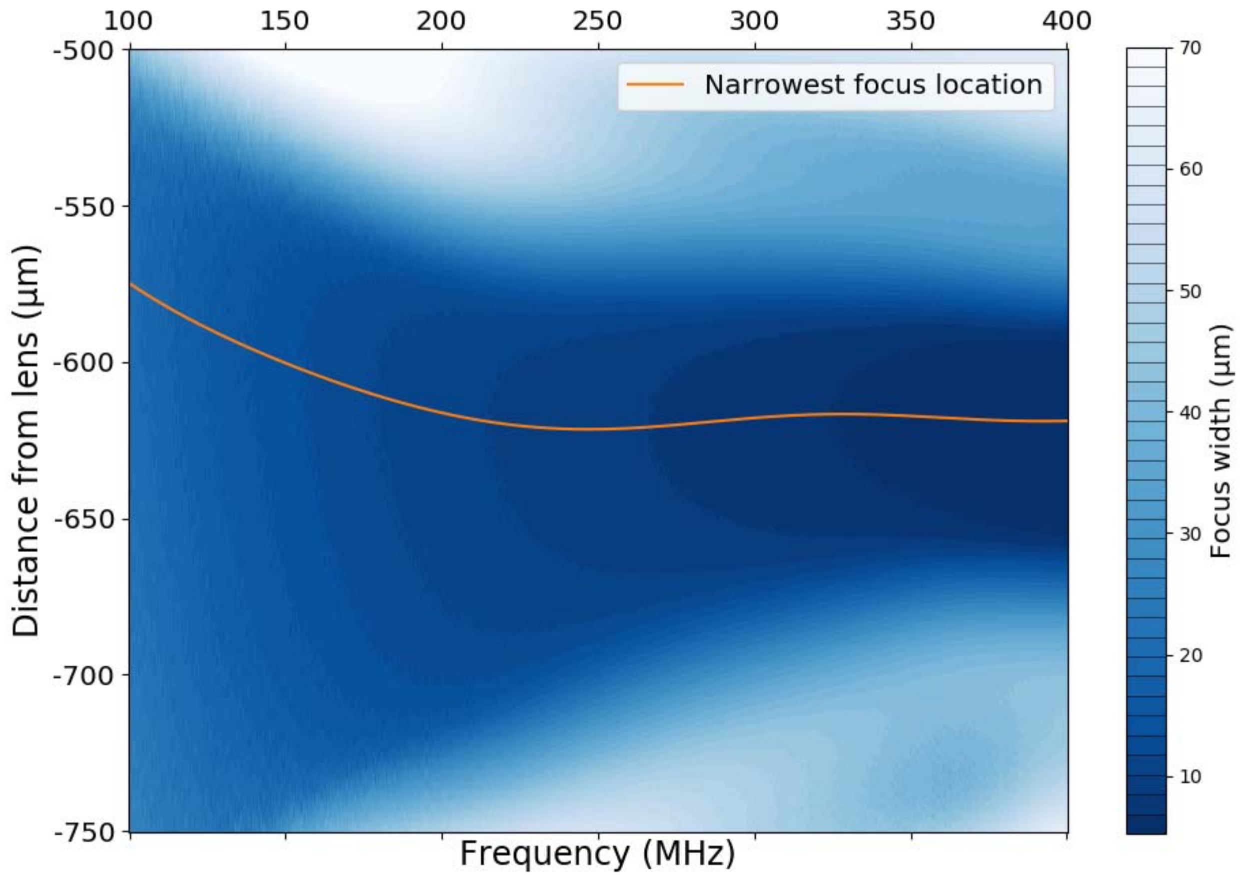
Results

- Comparison of results both in time- and frequency domain
  - Location of narrowest focus and intensity peak have similar frequency dependency
  - Time- and frequency domain results correspond to each other

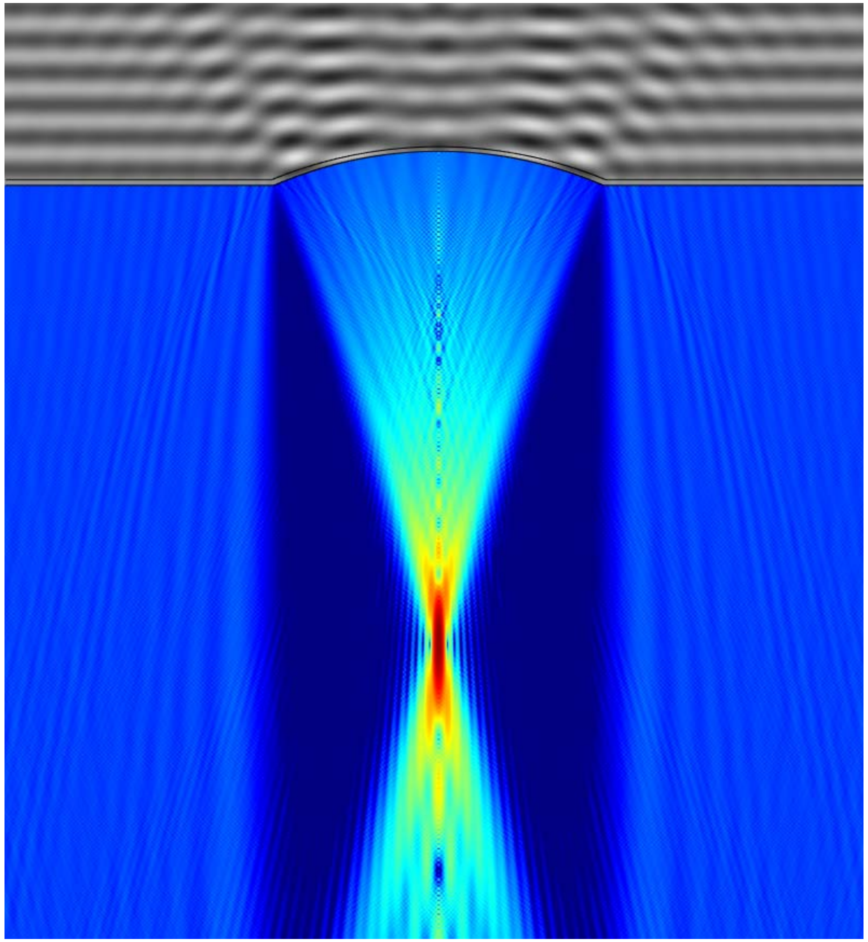


Results

- Frequency dependency of focus width
- Model for measurement data postprocessing



Conclusions



- Simulation results show that focusing of SAM has frequency dependency

- Postprocessing method can be made based on simulation results
  - Enhanced imaging resolution