# Modeling of bar-mode based single crystal ultrasound probes with a hybrid Finite Difference-Pseudo-Spectral Time Domain method

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## Background, Motivation and Objective

Most of modern ultrasound probes architectures rely on the perfect understanding of the well-known single crystal bar-mode. Optimizing such a structure needs accurate and performant modeling tools for efficient designs. To combine the advantages of finite-difference (FD) and pseudo-spectral time-domain (PSTD) methods (adaptability to model piezoelectric elements and low number of nodes per wavelength required), a hybrid FD-PSTD algorithm was previously developed to simulate both the electroacoustic behavior of annular arrays and the propagation of acoustic waves over large distances using a single model. The aim of this study is to take benefits of the FD-PSTD approach and apply it to the specific the specific geometry of bar-mode single crystal phased arrays.

## Statement of Contribution/Methods

Two simplified single crystal arrays (backing block, single crystal totally diced and silicone lens - without matching layers for the purpose of the study) have been specifically designed by Vermon company: one with kerfs filled with silicone (2,42MHz central frequency; 70% relative bandwidth at -6dB), the other with kerfs filled with air (1,92MHZ; 43%). As the PSTD method is sensitive to sudden variations in impedance (Fourier transform calculation), stresses were set to zero in kerfs filled with air, thus simulating a large impedance mismatch at the crystal/air interface. Figure 1 (left) represents an example of the simulated displacement generated by one element of a phased array with silicone kerfs. To validate the model, different measurements were made, related to the same quantities that are calculated by the simulation: electrical impedance, displacement of the transducer surface and acoustic pressure.

## Results/Discussion

As it can be seen on Fig. 1 (right) for the radiated pressure in the case of the air kerf transducer, the numerical code presents results close to the experimental measurements. A certain error (around 10%) has been observed on the frequencies of displacement and impedance of the air-kerf devices, surely because of the approximation made in having set the constraints to zeros. Another source of error may rely on the uncertainty of the mechanical and electrical parameters used in the numerical model. As a perspective, this adapted algorithm will be used to optimize performances of new single crystal probes (frequency response, inter-elements coupling, …).

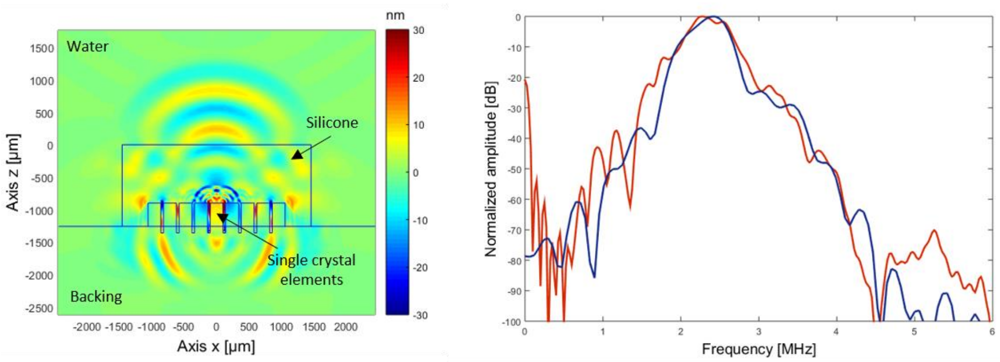


Fig.1. (Left) Simulated displacement in the case of a transducer with kerf filled with silicone (only the central element is excited); (Right) Frequency response of the pressure radiated in water, 1mm in front of the transducer with air kerf (red: measurement; blue: simulation).