EFFICIENT, SELECTIVE PIEZOELETRIC WAVE TRANSDUCTION USING INTERDIGITATED ELECTRODES

COM VS. COMSOL

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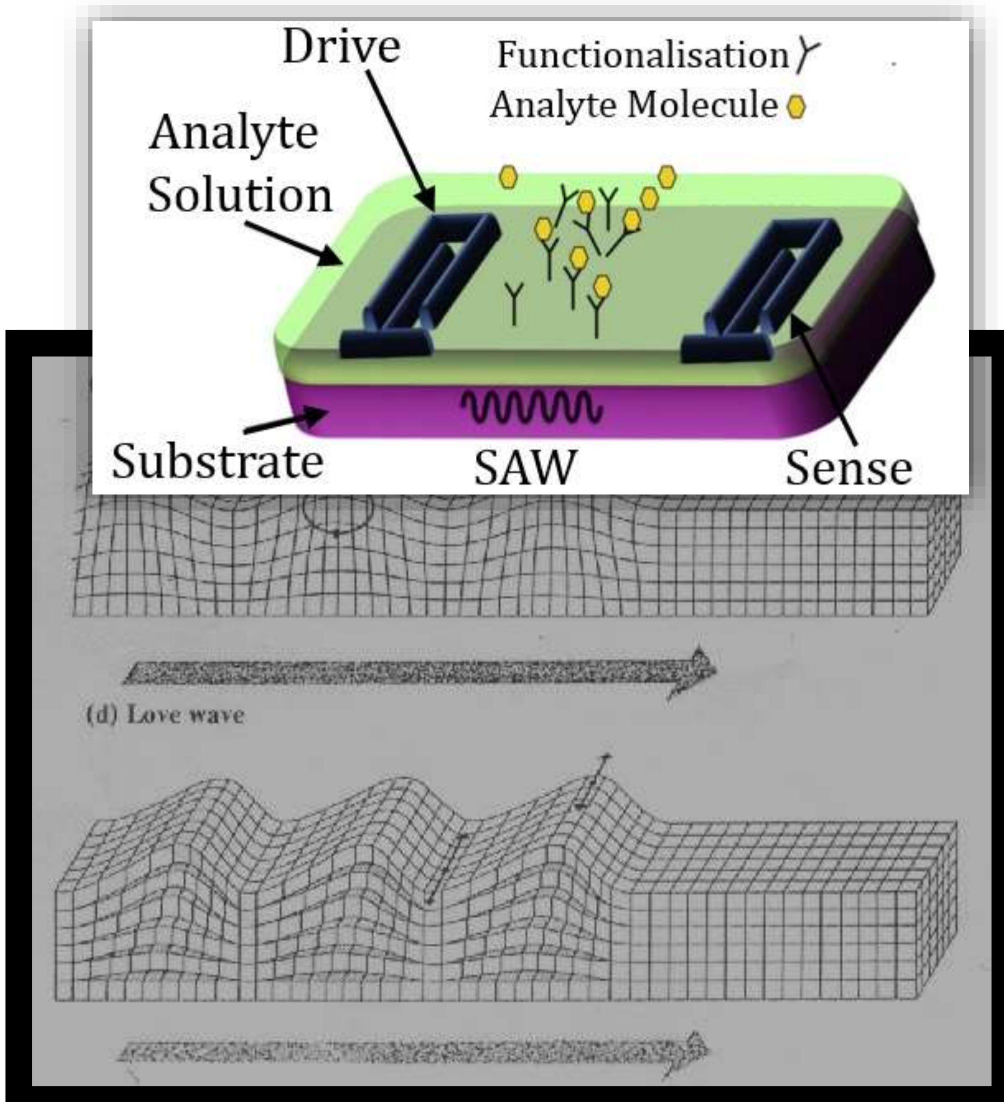
THE REVOLUTION

- We are living through a time of great change
- People are living longer than ever
- Medical technology is growing in importance every day
- Biosensors enable a whole new medical paradigm
- Potential to save and improve millions of lives

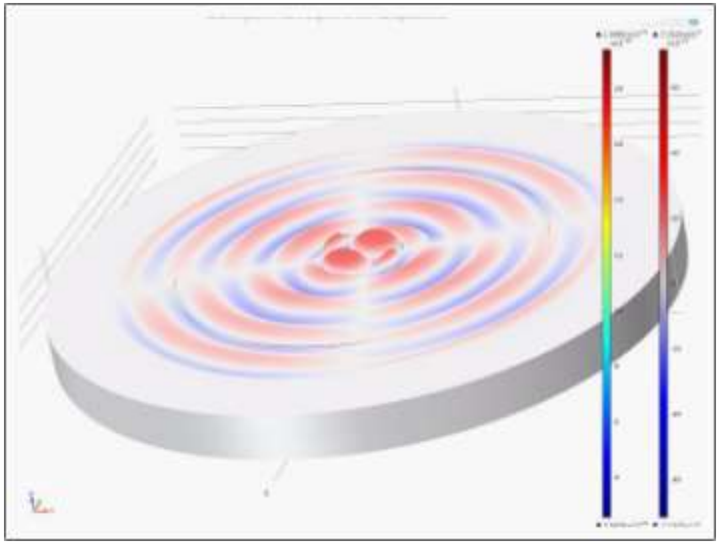
SAW BIOSENSORS

- **MEMS technology**
- **Surface Acoustic Waves**
- **Biochemical concentrations as measurands**
- **"Lab-on-a-chip"**



DSAW

- **Degenerate SAW technology**
- **NU IP[5][6]**
- **Label Free Mass Biosensor**
- **Next level performance**
- **Original theory developed using RRM Method[1] and analytical approaches**



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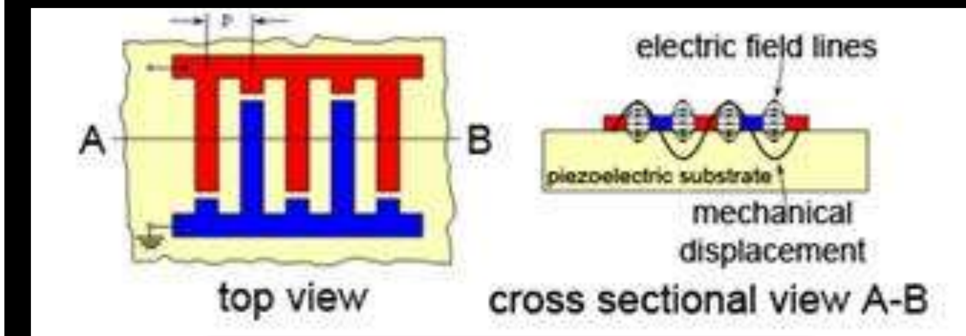
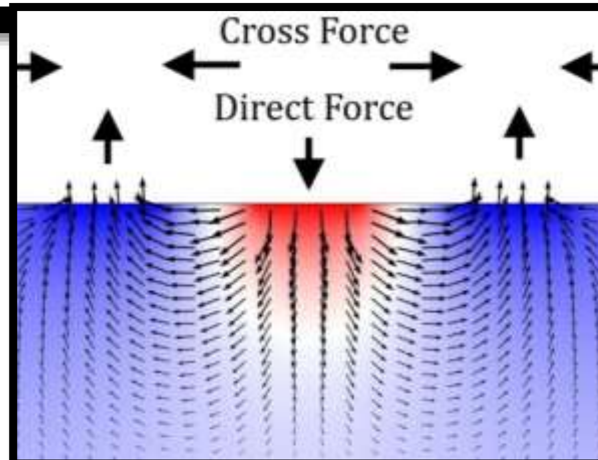
SAW TRANSDUCERS

- **Interdigitated Transducer**
- **Lithographically deposited**
- **Generates a controlled electric field**
- **Coupled via reverse piezoelectric effect to mechanical vibrations**





$$s_{ik} - C_{ijkl}\epsilon_{jl} + e^{T}_{kij}E_k = 0$$

$$D_i - e_{ijk}\epsilon_{jk} + \varepsilon_{ij}E_j = 0$$

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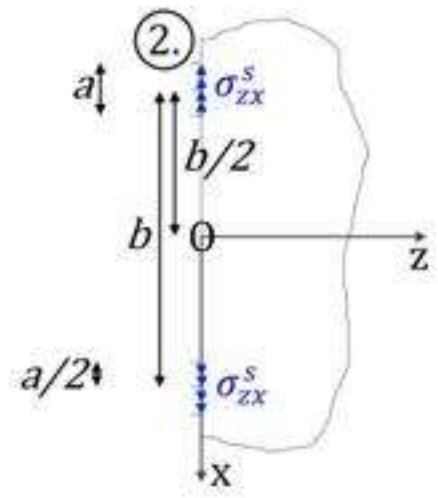
COM MODEL I

- **Purely mechanical, isotropic, semi-analytical**
- **Based on equivalent stress sources and approach in [4]**
- **Not easy to account for effects of inhomogeneity**
- **Independently validated via COMSOL**



$$c_{11}\nabla(\nabla.\mathbf{u}) + c_{44}\nabla \times (\nabla \times \mathbf{u}) = \rho \frac{\partial^2 \mathbf{u}}{\partial t^2}$$

$$\mathbf{A} = \nabla \times \mathbf{u} = \Psi(x, z)\mathbf{j}$$

$$\Phi = \nabla.\mathbf{u} = \varphi(x, z)$$

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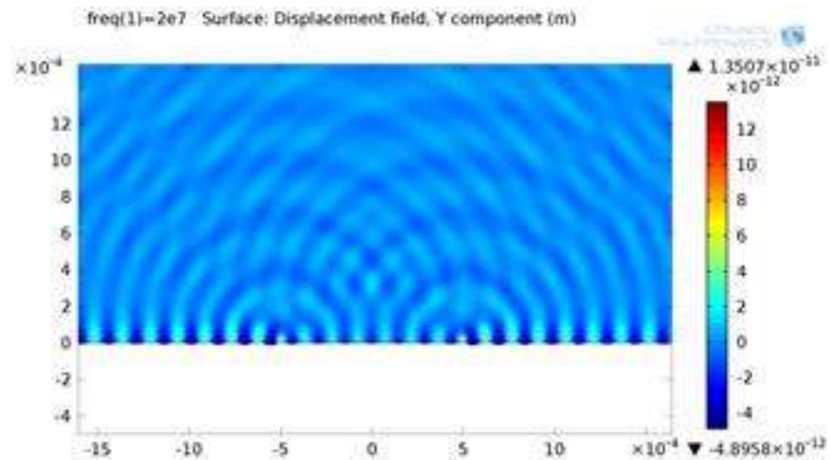
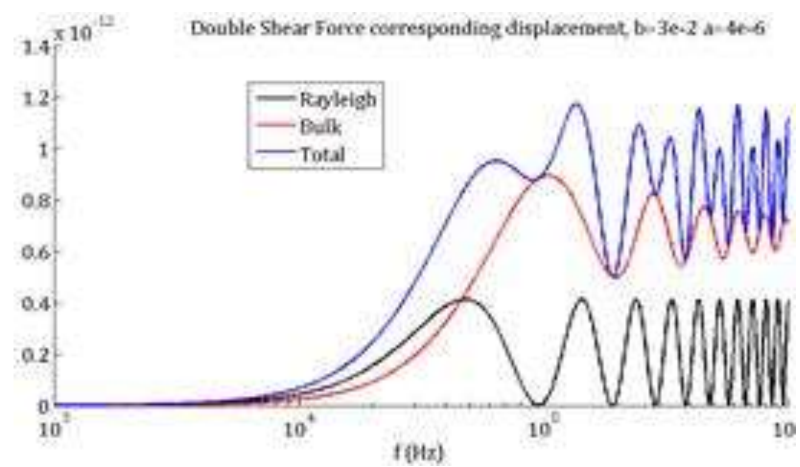
COM MODEL II

- **Good agreement in displacements**
- **Gives frequency response spectra**
- **See Ch. 3, Ref. [2] for more detail**

$$\overline{\mathrm{u}_x^s} = \frac{F_\mathrm{N}}{2a\rho d\pi v_\Psi^2}\int_{-a/2}^{a/2}\int_{0}^{\infty}\frac{i\xi}{\mathcal{S}}(\mathcal{R}$$





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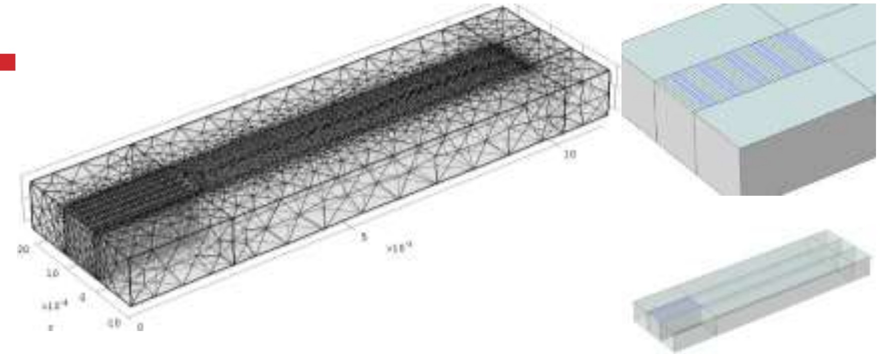
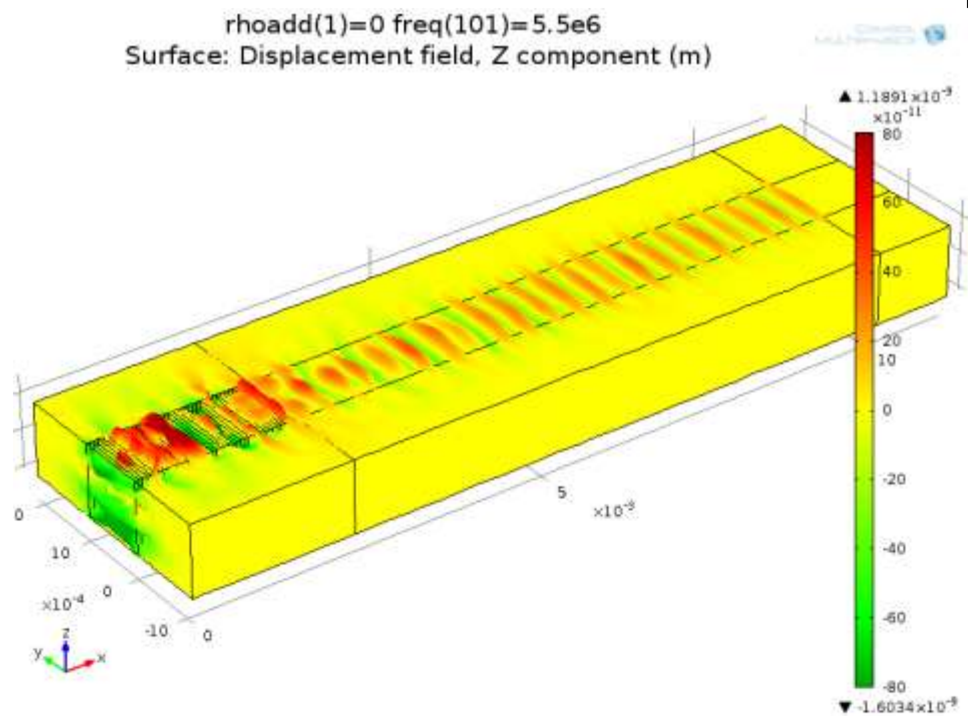
COMSOL MODEL

- **Piezoelectric Devices (PZD) Physics**
- **Frequency Domain study**
- **Uses PML to simulate free response**
- **Models double-digit IDT design on PZT**





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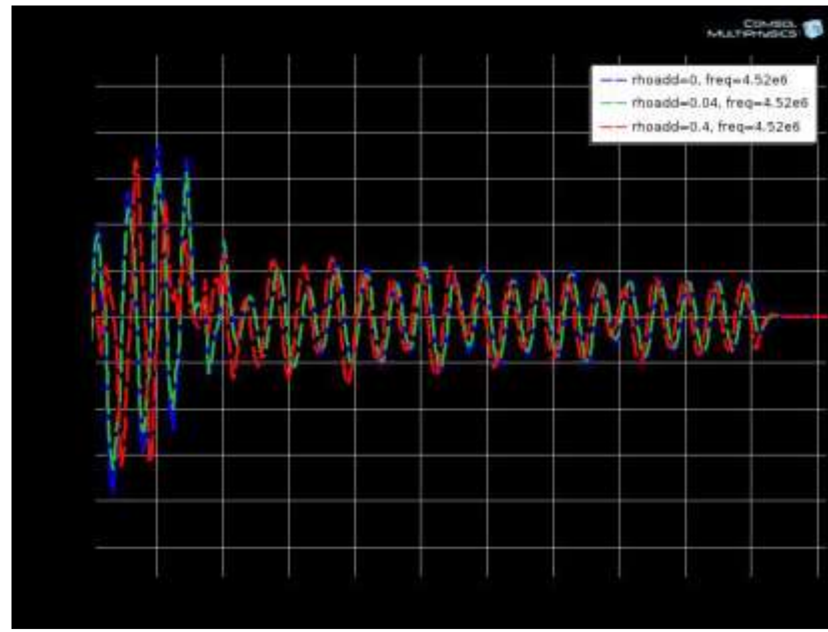
COM/COMSOL RESULTS

- **Model predictions compared in time and frequency domains**
- **COM model predicts wavelengths adequately**
- **Significant relative phase shifts observed due to mass loading, electromechanical interaction and anisotropy in COMSOL**



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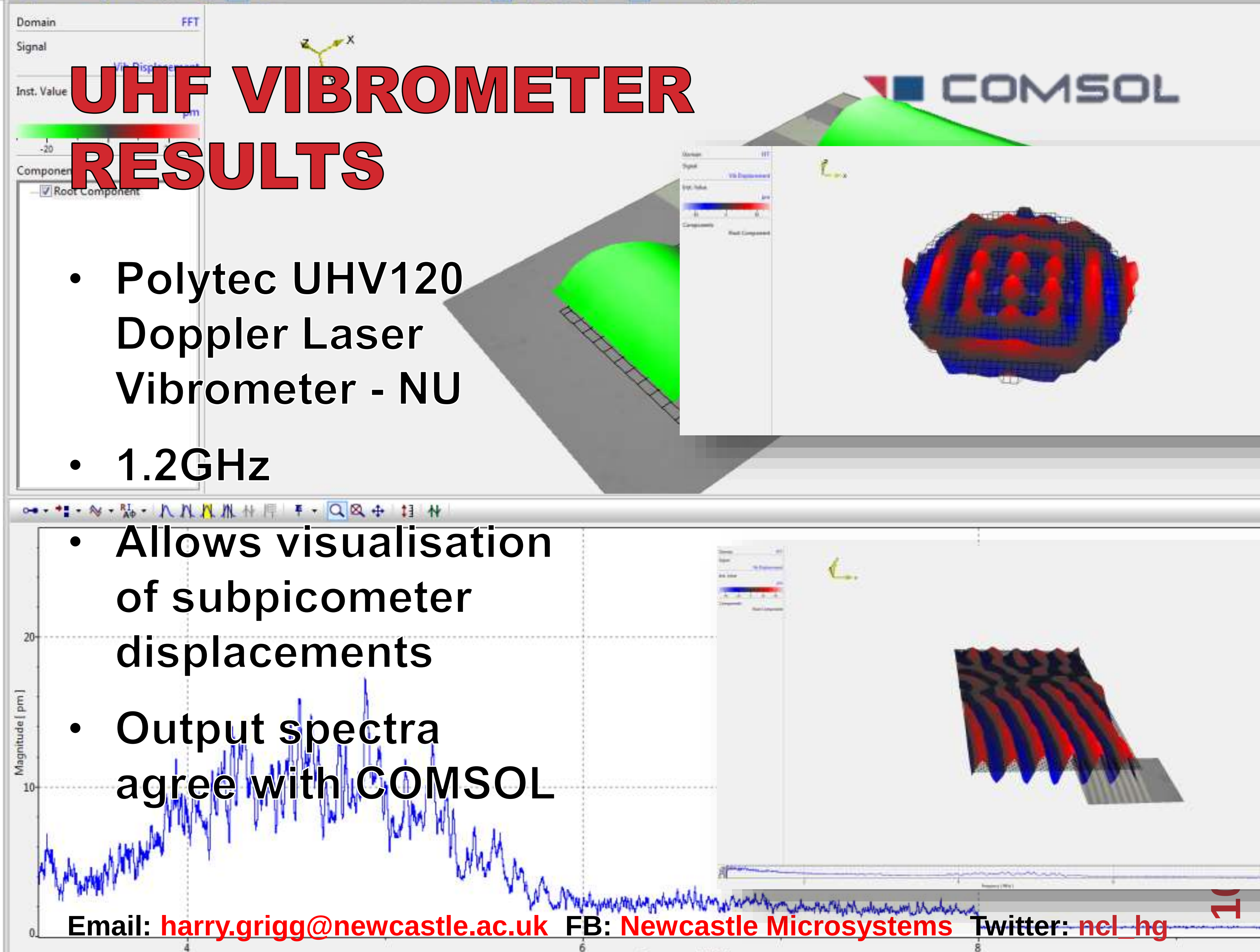
UHF VIBROMETER RESULTS



- Polytec UHV120 Doppler Laser Vibrometer - NU
- 1.2GHz
- Allows visualisation of subpicometer displacements
- Output spectra agree with COMSOL

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FUTURE DIRECTIONS

- Working with world-class ICM@Newcastle University
- Proof of Concept
- System level integration, fluidisation
- Next Generation Diagnostics

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CONCLUSIONS

- A new generation of biosensors is being developed at Newcastle University
- COMSOL Multiphysics offers significant advantages and synergies with respect to traditional analytical design techniques

REFERENCES

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2. H.T.D. Grigg, *Principles and Practice of the Xylophone Bar Magnetometer,* PhD Thesis, Newcastle University, 2014
3. H.T.D. Grigg, "Modal Degeneracy and Symmetry Breaking in Microsystems", COMSOL Conference Rotterdam, 2013
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5. H.T.D. Grigg and B.J. Gallacher, "Efficient Parametric Optimisation of Support Loss in MEMS beam resonators via an enhanced Rayleigh-Ritz method", *J. Phys. CS*., 2012
6. UK Patent EP1358475B1
7. US Patent US20040051539B1: bioMEMS

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