Modeling of PZT Slab for Generating Symmetric and Uniform Axial Strain Distribution

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INTRODUCTION: Lead Zirconate Titanate (PZT) ceramic slabs are utilized for modulating Fiber Lasers (FLs) for interferometric fiber optic sensing applications. Mounting of FLs on PZT slabs is a critical requirement for many fiber optic sensing systems. Careful design of PZT slabs is important for achieving uniform, symmetric & optimum modulation among multiple FLs in such applications, otherwise it affects functionality of FLs. The axial strain on the PZT slabs is analysed through COMSOL FEM by varying its dimensions and material compositions for different modulation frequencies and different regions on slab. PZT8 & PZT 5H slabs are designed and analysed for high frequency optical modulation requirements.

COMPUTATIONAL METHODS: COMSOL Multiphysics software version 5.3 is utilized to model and evaluate the performance of the PZT slabs at different electric potentials. The frequency resonant states, displacement and the axial strain on PZT slabs are analyzed. Piezoelectric & mechanical structure properties are analyzed using piezoelectric devices & solid mechanics interfaces from the structural mechanics module. The Electric field to PZT model is simulated using electrostatics interface in AC/DC module. For analysis, frequency domain is selected in study module. Default boundary condition is considered for the model. Equations used for computation are

$$-\rho\omega^2 \boldsymbol{u} = \nabla . \boldsymbol{S} + \boldsymbol{F_V} e^{i\phi}$$

$$\nabla . \boldsymbol{D} = \rho_V$$

$$\boldsymbol{E} = \nabla \boldsymbol{V}$$

RESULTS:

Simulation results of PZT8 Slab

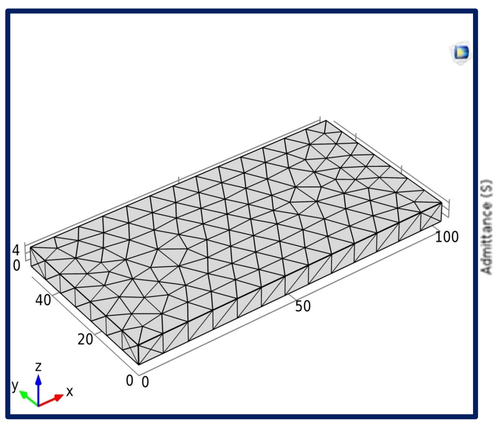

Figure 1. Dimension of PZT8 slab

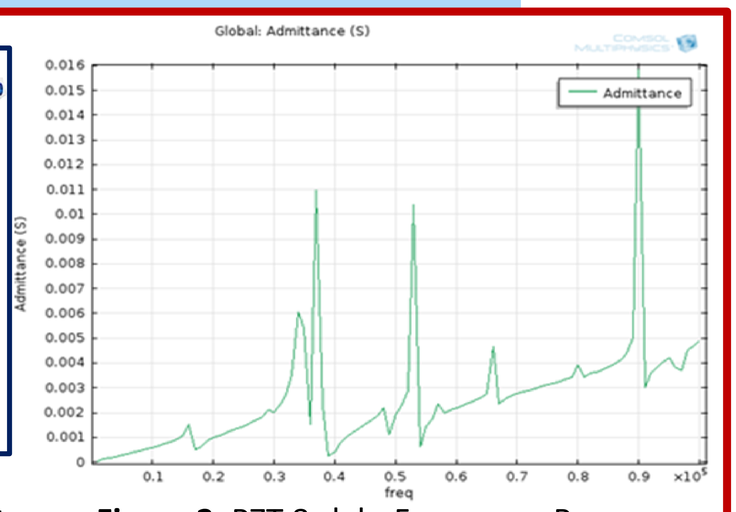

Figure 2. PZT 8 slab_Frequency Response

Axial strain @ 45 kHz modulation signal of amplitude 1 V

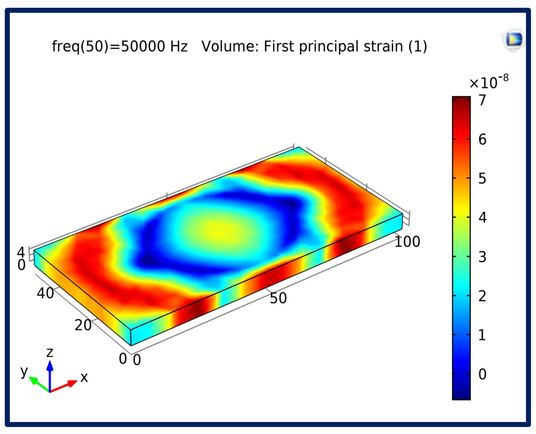

Figure 3. Surface strain on slab

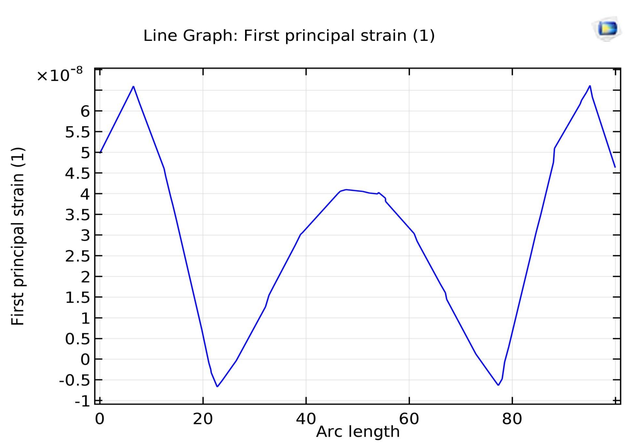

Figure 4. Strain plot across center axis of slab

Axial strain @ 50 kHz modulation signal of amplitude 1 V

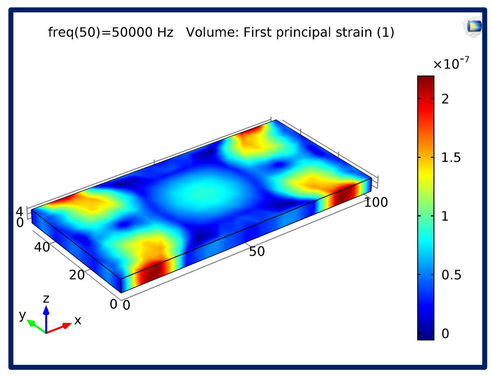

Figure 5. Surface strain on slab

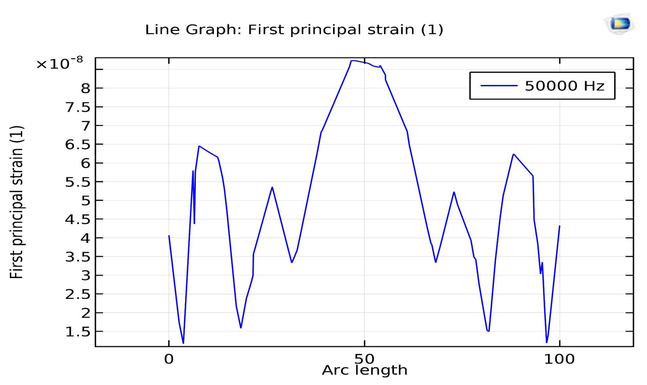

Figure 6. Strain plot across center axis of slab

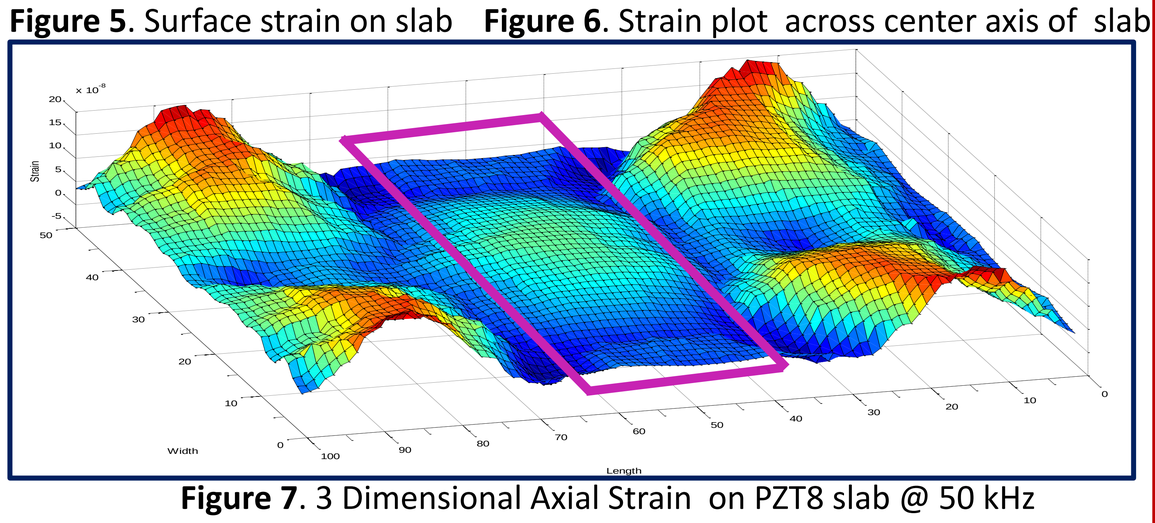

Figure 7. 3 Dimensional Axial Strain on PZT8 slab @ 50 kHz

Simulation results of PZT5H Slab

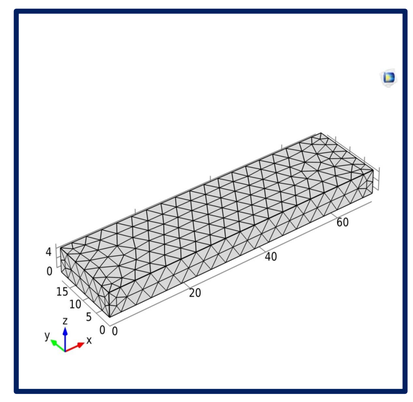

Figure 8. Dimensions of PZT5H slab

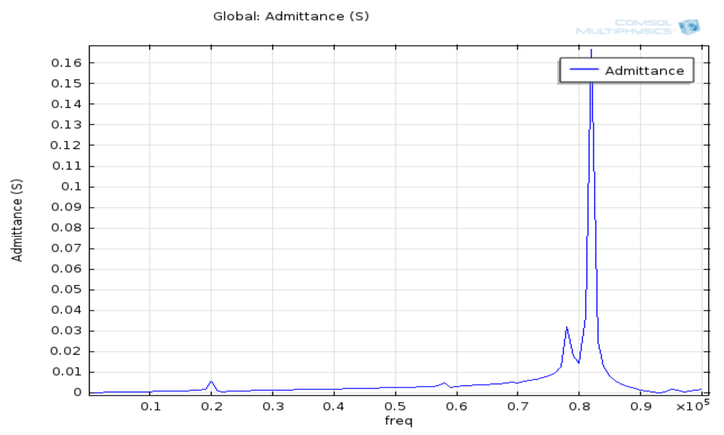

Figure 9. Frequency Response

Axial strain @ 50 kHz modulation signal of amplitude 1 V

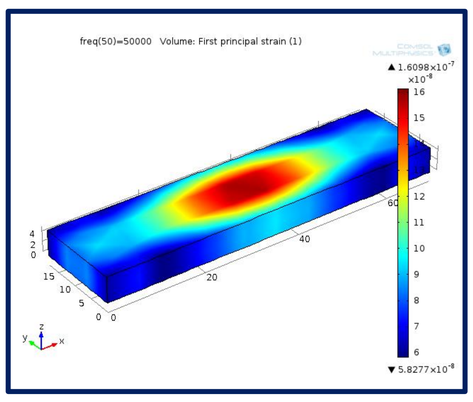

Figure 10. Surface strain on slab

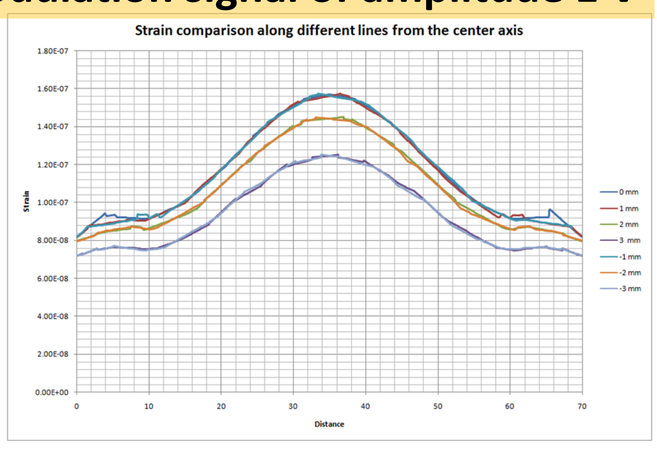

Figure 11. Strain plot at different Points on slab

CONCLUSIONS:

- Realized the optimum & symmetric strain distribution on PZT slabs at high modulating frequencies.
- Identified a suitable region on PZT slab for generating uniform frequency modulation on fiber lasers.
- Realized the significance of PZT material composition & its Dimensions for required axial strain distribution and optimum frequency response.

REFERENCES:

1. C. Kirkendall and A. Dandridge, "Overview of high performance fiber- optic sensing'' *Journal of Physics D: Applied Physics,* vol. 37, 2004, pp. R197–R216.
2. A. Cekorich, "Demodulator for interferometric sensors," in *Fiber Optic Sensor Technology and Applications*, vol. 3860. International Society for Optics and Photonics, 1999, pp. 338–348.
3. A. C. Jeff Bush, "Low-cost interferometric tdm technology for dynamic sensing applications," pp. 5589 – 5589 – 12, 2004. [Online]. Available: https://doi.org/10.1117/12.570673

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