MICRONOVA
CENTRE FOR MICRO- AND NANOTECHNOLOGY
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MICROACOUSTIC DEVICES: MODELLING AND OPTICAL ANALYSIS

MICROACOUSTIC DEVICES GROUP

OPTICS AND MOLECULAR MATERIALS LABORATORY

The last two decades have witnessed a massive growth of the telecommunication industry. Among the technical prerequisites for modern cellular and cordless systems are radio-frequency (RF) filters featuring small size and minimal losses. For this demanding application, a novel class of components based on the surface-acoustic wave (SAW) and bulk acoustic wave (BAW) technology has emerged. A work of art in miniaturization, the SAW technology combines sophisticated engineering with the physical properties of the piezoelectric crystals, enabling excellent filtering performance. Similarly, the BAW technology achieves this goal by using sputtered piezoelectrical thin-films. Radio-frequency SAW and BAW bandpass filters are now widely employed in modern cordless and cellular telecommunication systems. In order to shed light on the huge volume of components produced by the industry, it should be mentioned that the number of radio frequency SAW filters alone exceeds 3 billion per year.

In addition to established SAW and BAW microacoustic devices, a novel group of microacoustic devices is emerging. Micromechanical resonators manufactured from silicon are seen as a potential technology for highly integrated communication circuits. Similarly to SAW and BAW tehnologies, mechanical oscillations are used to achieve high Q values and high performance. Often referred to as RF-MEMS components, these devices enable significant component size reduction in comparison to the traditional quartz oscillators.

RECENT RESULTS

Our research group focuses on modelling existing as well as novel SAW and BAW component designs with the help of numerical simulation tools, see Publ.1, 2, 5 and 7. In addition we have developed two unique laser-interferometers for directly measuring the minute surface vibrations occuring in SAW, BAW and RF-MEMS components, see Fig. 1 and Publ. 3, 4, 6 and 8. These scanning interferometers provide a three-dimensional image of the surface vibrations and reveal the true acoustical operation, including possible problems e.g. acoustic losses, of the microacoustic device, see Fig 2. Such information is impossible to obtain via electrical measurements alone. Furthermore, the measured data can be compared against simulated acoustic behavior providing unique feedback for further development of numerical tools such as FEM/BEM and phenomenological models.

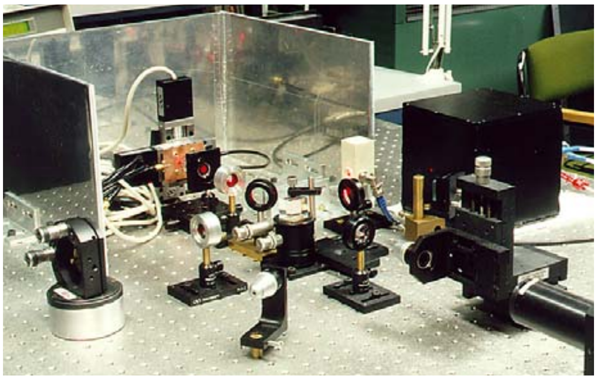

Figure: 1. A scanning Michelson interferometer capable of measuring surface vibrations at frequencies as high as 2.5 GHz with amplitudes on the order of a few picometers. The spatial resolution of the measurement is better than 1μm. Computer control enables a large number of data points to be collected at measuring speeds reaching over 50 000 points per hour.

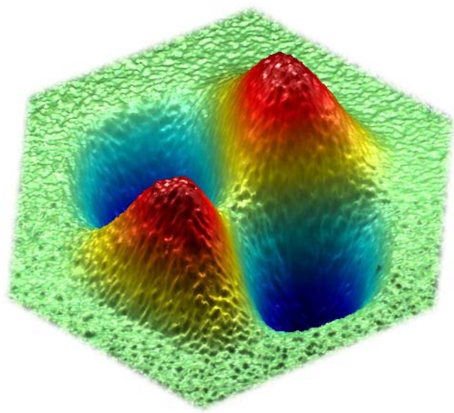

Figure 2. Vibrations of a micromechanical membrane resonator at 3.836 MHz. Our second interferometer utilizes optical heterodyning in order to provide absolute amplitude as well as phase information of the surface vibrations. The phase information can be used to create a 3D view and a time lapse movie of the surface vibrations.

Funding

Academy of Finland (TULE - the Future Electronics Programme), Finnish Cultural Foundation, Alfred Kordelin Foundation, Magnus Ehnrooth Foundation, and Research Council of HUT. In addition we carry out several industry-commissioned projects.

Industrial Partners

TEMEX, RF SAW Inc.

Research Collaborators

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Recent Publications

1. J. Meltaus, V.P. Plessky, S. Härmä, and M.M. Salomaa, *SAW Filter Based on Parallel-Connected CRFs with Offset Frequencies*, IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, (to appear).
2. J. Meltaus, V.P. Plessky, S. Härmä, and M.M. Salomaa, Low-Loss, Multi-Mode 5-IDT SAW Filter, IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control **52**, 1013-1019 (2005).
3. O. Holmgren, J.V. Knuuttila, T. Makkonen, K. Kokkonen, V.P. Plessky, W. Steichen, M. Solal, and M. M. Salomaa, *Imaging surface-acoustic fields in a longitudinal leaky wave resonator*, Applied Physics Letters **86**, 024101 (2005).
4. O. Holmgren, K. Kokkonen, T. Mattila, V. Kaajakari, A. Oja, J. Kiihamäki, J.V. Knuuttila, and M.M. Salomaa, *Imaging of in- and out-of-plane vibrations in micromechanical resonator*, Electronics Letters **41**, 121-122 (2005).
5. T. Makkonen, T. Pensala, J. Vartiainen, J.V. Knuuttila, J. Kaitila, and M.M. Salomaa, *Estimating Materials Parameters in Thin-Film BAW Resonators Using Measured Dispersion Curves*, IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control **51**, 43-51 (2004).
6. J.V. Knuuttila, J.J. Vartiainen, J. Koskela, V.P. Plessky, C.S. Hartmann, and M.M. Salomaa, *Bulk-acoustic waves radiated from low-loss surface-acoustic-wave resonators*, Applied Physics Letters **84**, 1579-1581 (2004).
7. J. Meltaus, V.P. Plessky, and S.S. Hong, *Double-Resonance SAW Filters*, Proceedings of the 2005 IEEE Ultrasonics Symposium (to appear). Note: Student paper competition winner 2005.
8. K. Kokkonen, J.V. Knuuttila, V.P. Plessky, and M.M. Salomaa, *Phase-Sensitive Absolute-Amplitude Measurements of Surface Waves Using Heterodyne Interferometry*, Proceedings of the 2003 IEEE Ultrasonic Symposium, 1145-1148. Note: Student paper competition winner 2003.