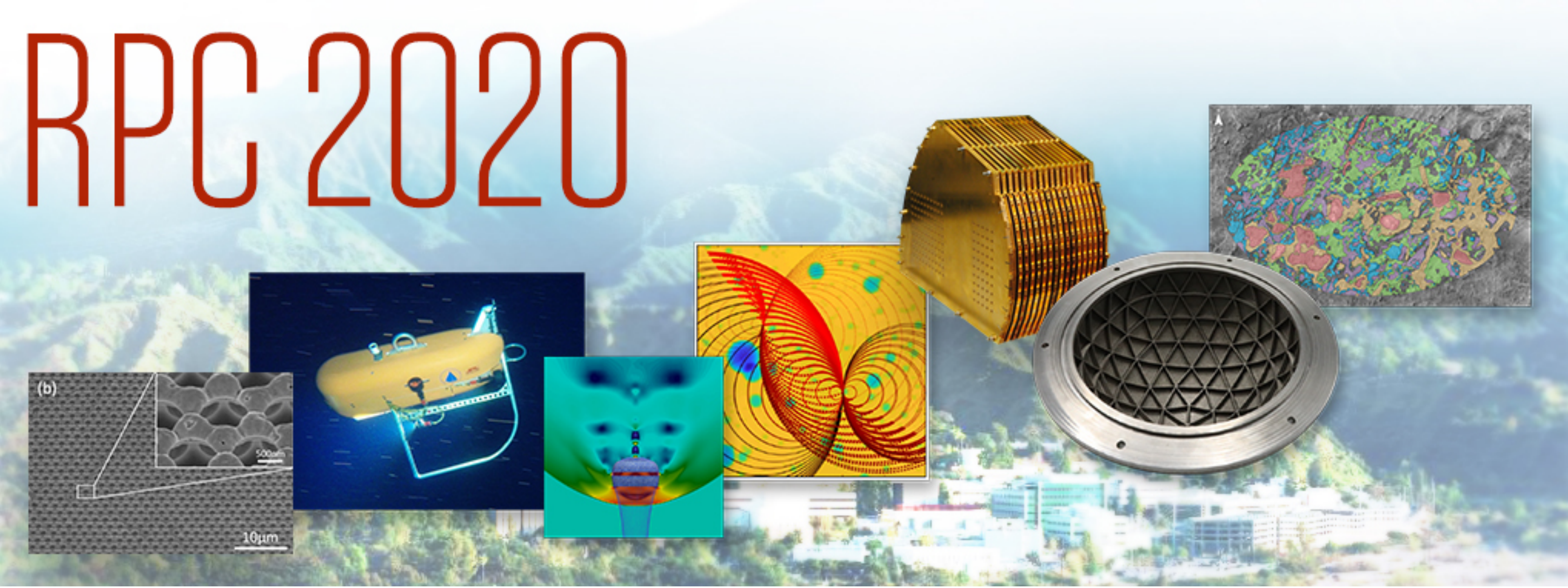

Virtual Research Presentation Conference

Surface acoustic wave tunable diffraction grating for imaging spectrometers

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Program: Topic RTD

Assigned Presentation # RPC226

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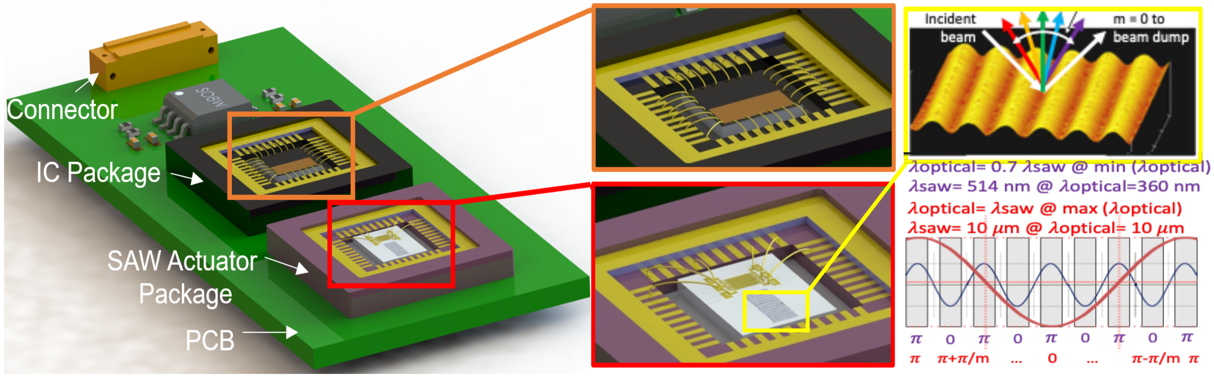
Tutorial Introduction

Abstract

Diffraction gratings are commonly used in optical instruments such as in spectrometers, monochromators, and wavelength division multiplexing devices. The diffraction efficiency is directly related to the ratio of the grating spacing or pitch to the wavelength of the light. To address a large spectral range, advanced spectrometers use a number of diffraction gratings with a fixed pitch. Here, we show for the first time, the use of a tunable-frequency surface acoustic wave (SAW) delay line as a broad-band sinusoidal diffraction grating. To tune the frequency, we tune the effective spacing of the interdigitated transducers (IDTs) by applying specific phases to each IDT finger. The prototype SAW grating covers frequency range of 86 MHz to 360 MHz corresponding to optical range of 1.3 μm to 9 μm.

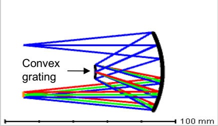
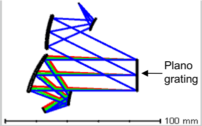


A schematic showing the device principle of operation. Instead of engraving gratings, the gratings are defined using surface acoustic wave. By tuning the frequency of the acoustic signal and/or changing the phase applied to the SAW actuator fingers, the pitch of the grating is changed to maximally diffract the optical band of interest.

Problem Description

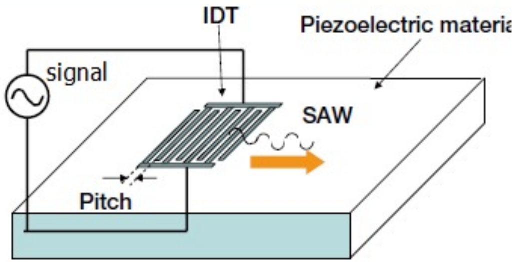
a) Context :The development of a tunable diffraction grating could enable future spectrometer designs that cover wavelengths from the visible through the shortest wavelength end of the infrared portion of the spectrum. For Mars, this advancement would allow co-located detections of iron-bearing, water-bearing, and silica-rich phases.

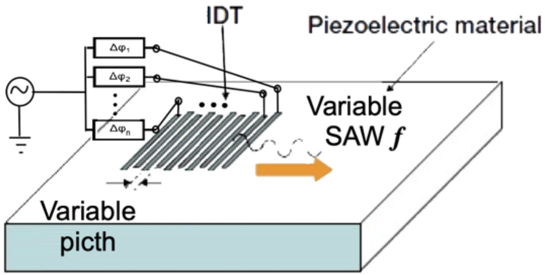
b) SOA (Comparison or advancement over current state-of-the-art)

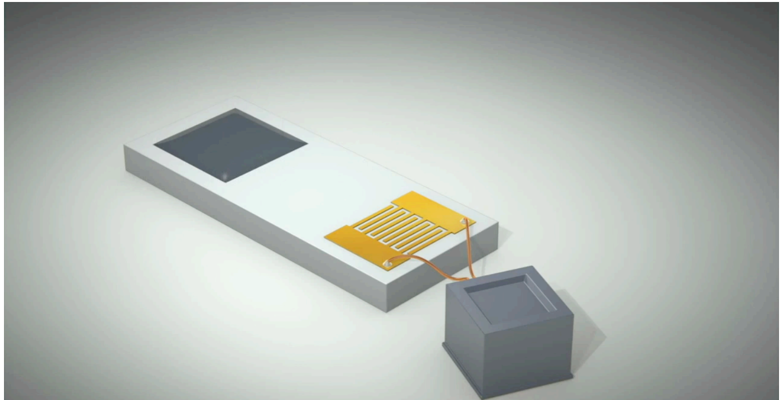
	JPL Ultra Compact Imaging Spectrometer (UCIS)	JPL Widely Tunable Imaging Spectrometer (based on the proposed work)
Optical Layout		
Base configuration	Unit magnification Offner, F/4	Unit magnification back-to-back off-axis Cassegrain, F/4
Spectral sampling	16 nm (at 1 um wavelength, 30 um camera pixel)	0.75 nm (at 1 um wavelength, 30 um camera pixel)
Spectral Coverage	350 – 2600 nm (demonstrated)	350 – 10,000 nm (to be demonstrated)

c) Relevance to NASA and JPL :This tunable diffraction grating lowers the SWaP/cost of the imaging instrument by combining 2 – 3 imaging spectrometers into 1. This technology will enable a new class of grating-based imaging spectrometer and will make JPL more competitive in the competed missions.

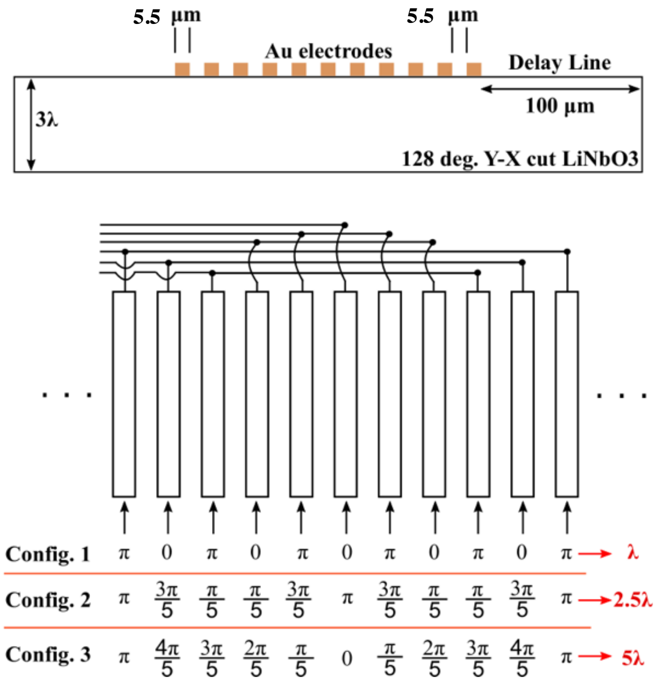
Methodology







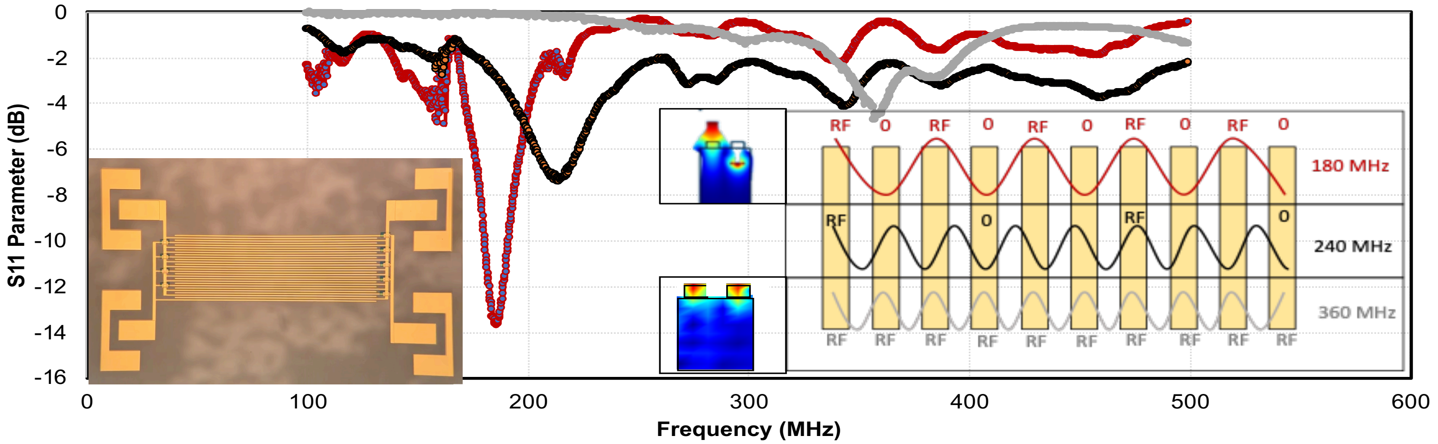
LEFT: a conventional SAW delay line, RIGHT: a schematic showing the concept of the tunable SAW actuator. Bottom: Video of the concept



2D schematic of the SAW device detailing the dimensions and materials used. (b) Three input configurations used in the simulations. In each configuration, input signals with the listed phases are applied to the designated electrodes to modify the resonance frequency and wavelength of the SAW device.

Results

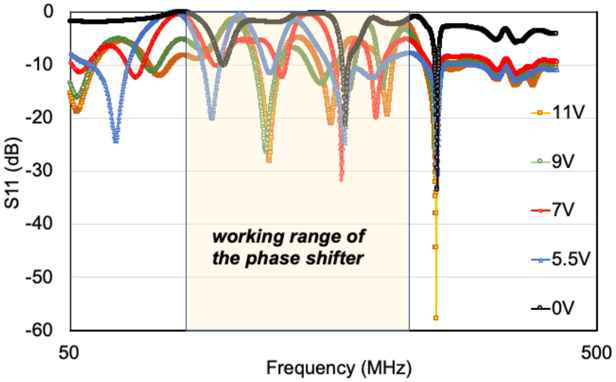
a) Accomplishments versus goals: We showed measured results of a tunable surface acoustic wave transducer that can be used to implement tunable diffraction gratings with wavelength range of 1.3 μm to 9 μm.



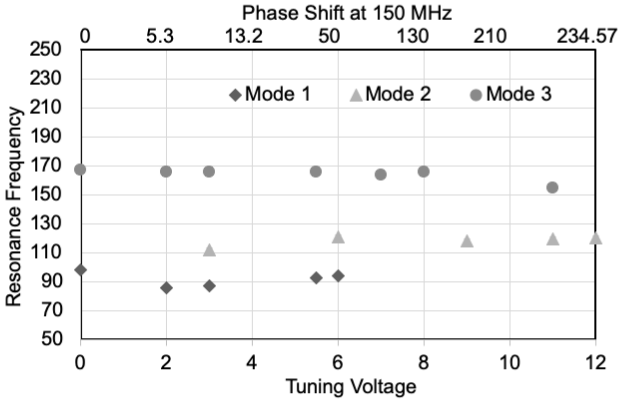
Measurement results of tunable SAW actuator on lithium niobate (without the phase shifter attached). The frequency response is tuned by changing the configuration of IDTs as shown in the inset. A picture of the fabricated tunable SAW device is also shown. The frequency is tuned from 180 MHz to 360 MHz.

Results

a) Accomplishments versus goals: We showed measured results of a tunable surface acoustic wave transducer that can be used to implement tunable diffraction gratings with wavelength range of 1.3 μm to 9 μm.



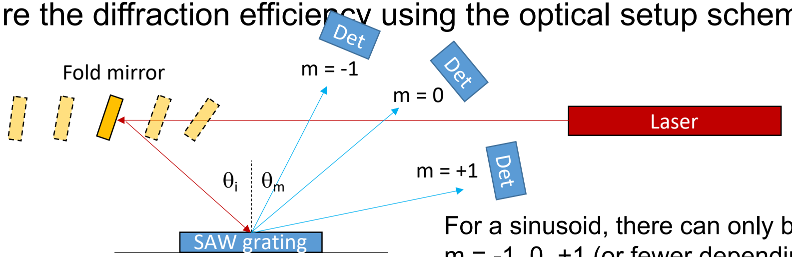
Measured S_{11} parameter of the SAW transducer as a function of the applied bias to the phase shifter.



Measured change in modal frequency with applied bias when Port 2 is connected to the phase shifter. Note that the phase shift (in degree) at frequencies > 200 MHz is negligible, thus 240 MHz mode does not change with bias.

Results

b) Next steps: The diffraction efficiency is estimated to be low (about 30%); next step is to improve this by coating the surface of the delay line with a polymer to achieve surface amplitude that is close to 1/10 of the optical wavelength. We will also measure the diffraction efficiency using the optical setup schematically shown below:



For a sinusoid, there can only be m = -1, 0, +1 (or fewer depending on θ_i).

Measure the laser power:
1. After the fold mirror
2. At m = 0
3. At m = +1
4. At M = -1
5. Move and point the fold mirror to another θ_i
6. Repeat 2 – 5 to map the diffraction efficiency $\eta(\theta_i)$

a) Significance: Such widely tunable diffraction gratings can enable instruments with improved science at planetary bodies across the solar system by permitting identification of a large number of surface materials at high spatial resolutions.

Publications and References

C. F. Frez, M. B. Coskun, V. J. Scott, Y. Wu, A. Fraeman and M. Rais-Zadeh, "Frequency Tunable Surface Acoustic Wave Actuators for Adjustable Pitch Diffraction Grating," in *Journal of Microelectromechanical Systems*, doi: 10.1109/JMEMS.2020.3000151