Aluminum Nitride Microchip Frequency Comb to Advance Exoplanet Discovery

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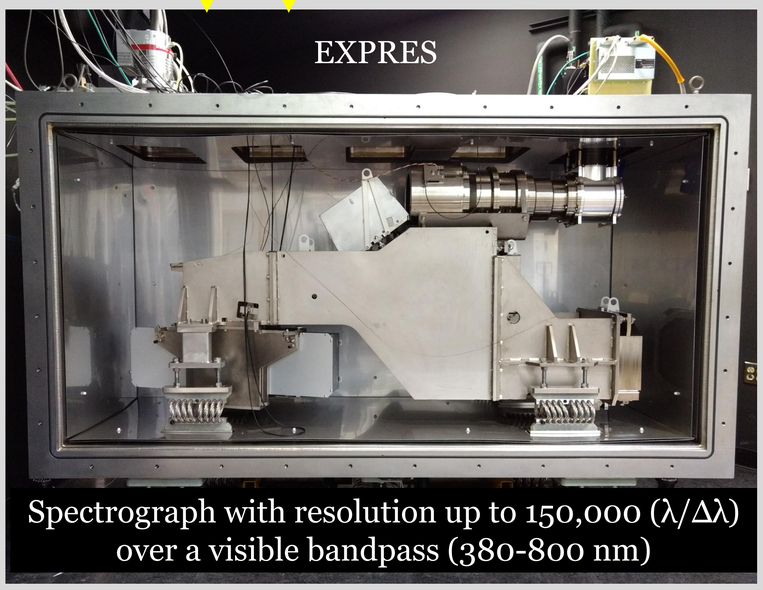
The EXtreme PREcision Spectrograph

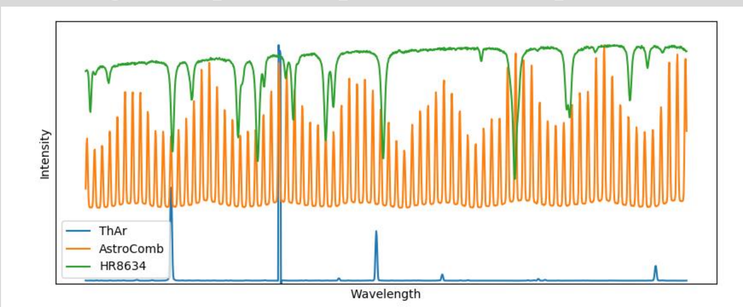
Light from V < 10 magnitude stars

Light from stable wavelength calibration sources



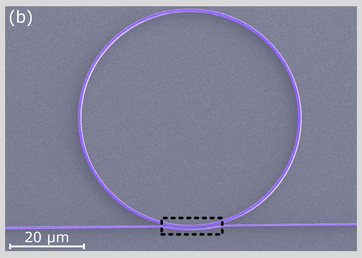
Spectrograph with resolution up to 150,000 (λ/Δλ) over a visible bandpass (380-800 nm)

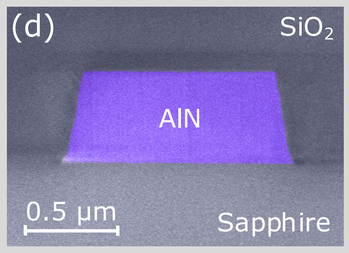
The ThAr spectrum roughly calibrates the AstroComb, which, in turn, measures the offset of stellar spectral lines. These offsets yield the radial velocity of the star. Periodicity in the radial velocity signal implies the presence of exoplanets.



Aluminum Nitride (AlN)

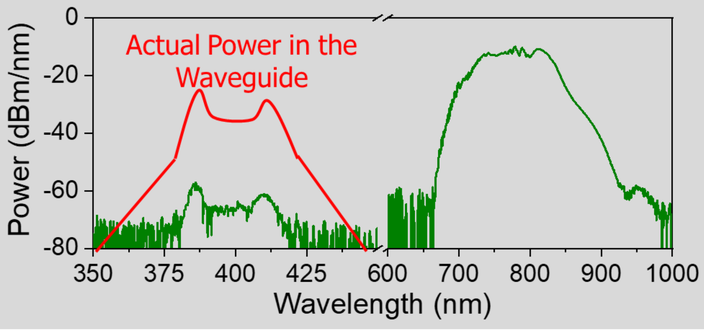
Optically nonlinear material being developed into microchip waveguides by the Yale Nanodevices Lab



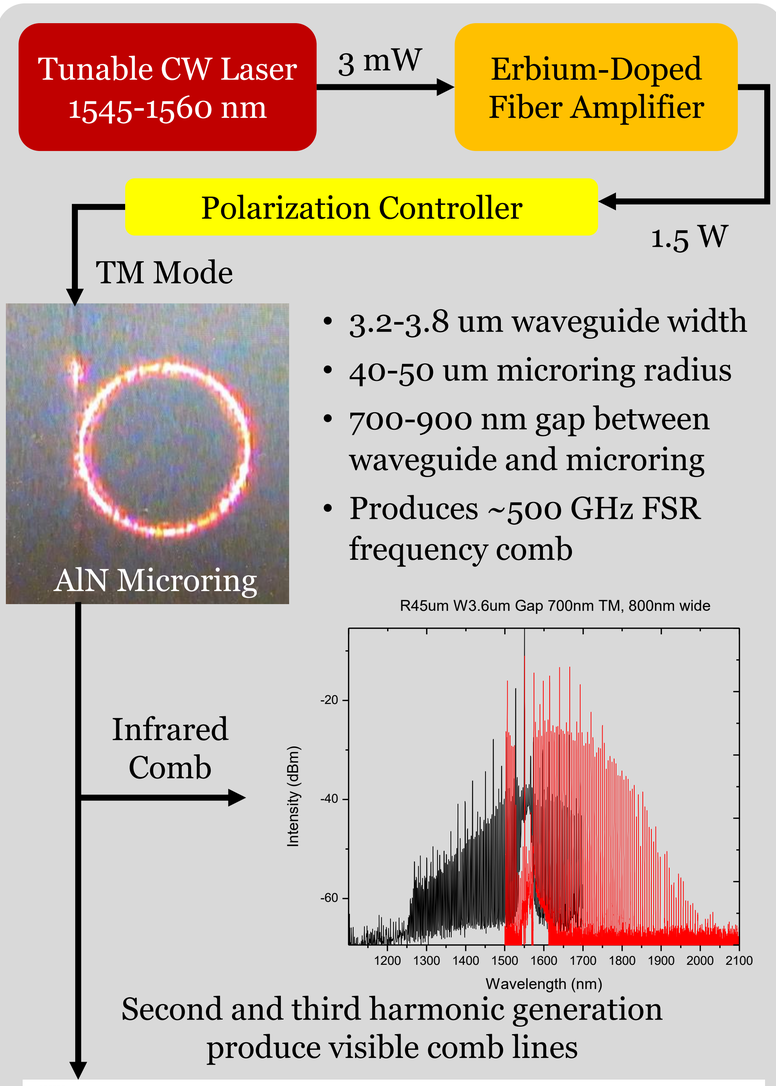


Extremely suitable for frequency comb generation:

- Widest bandgap among all semiconductors
- Known for UV (below 450 nm) transparency
- Strong second-order optical nonlinearity, enabling frequency doubling and self-referencing
- Can be easily fabricated into compact chips

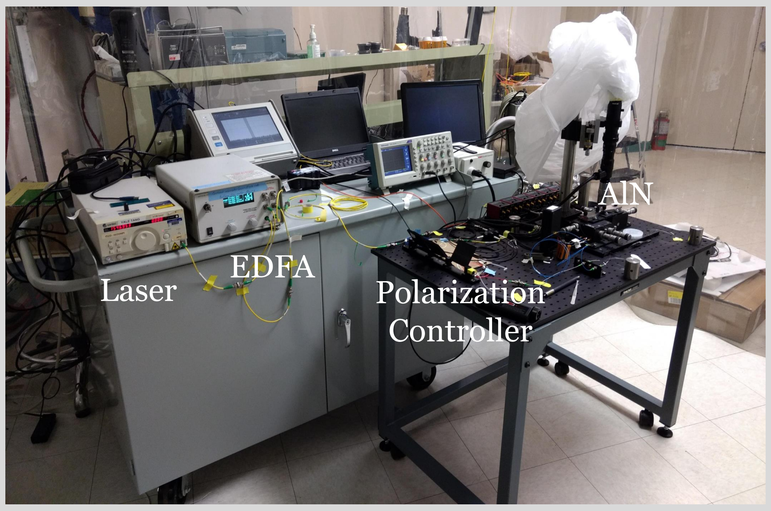


AlN Microring Resonator



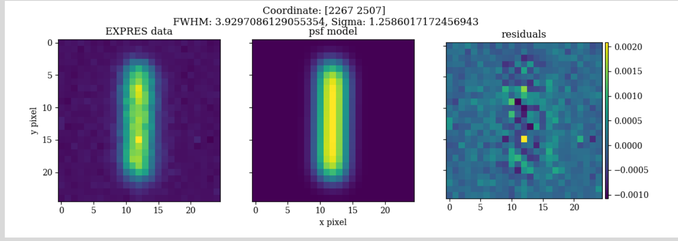
- 3.2-3.8 um waveguide width
- 40-50 um microring radius
- 700-900 nm gap between waveguide and microring
- Produces ~500 GHz FSR frequency comb

Microcomb Setup at the Discovery Channel Telescope



Point Spread Function Modelling

We use data from the microring resonator to measure the point spread function of EXPRES and more precisely extract high resolution spectra.



EOM + AlN Waveguide Astro-comb

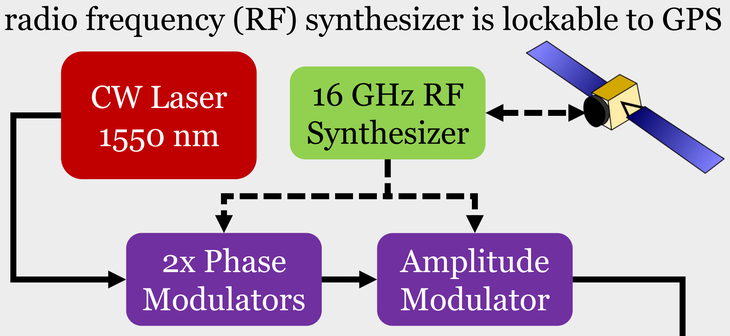
As a supplement (or alternative) to the Menlo AstroComb, we are developing an astro-comb based on a straight AlN waveguide. To be suitable for precision radial velocity measurement on EXPRES, this comb must:

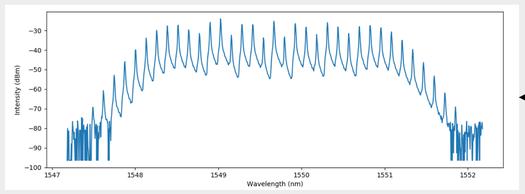
1. Have a night-to-night precision of 10^{-11}
2. Have an FSR of >10 GHz and <30 GHz
3. Cover a significant portion of EXPRES's spectral range (380-800 nm)

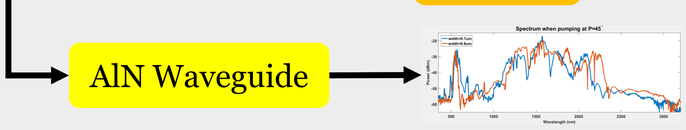
Therefore, we combine a 16 GHz Infrared Electro-Optic Modulation (EOM) comb with the AlN waveguide. This gives us the tunability and stability of EOM technology along with the spectral broadening of the AlN.

EOM Comb

The laser is finely tunable via temp control and the radio frequency (RF) synthesizer is lockable to GPS

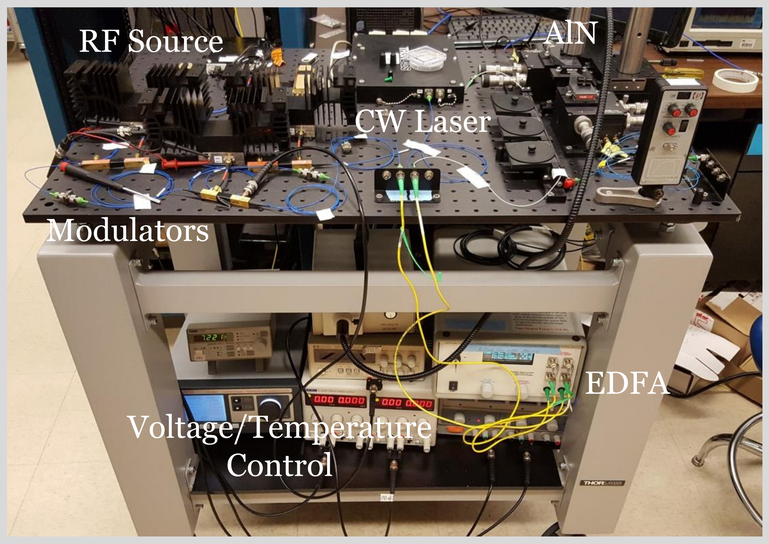






Spectral Broadening (work in progress)

After amplification and dispersion compensation through both single-mode fiber (SMF) and highly nonlinear fiber (HLNF), supercontinuum generation can be induced in the AlN waveguide



Prototype EOM + AlN astro-comb inside the Tang Lab in the Malone Engineering Center

Acknowledgements

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