A Miniaturized Cryogenic Scanning Fabry-Perot (MCSF) Interferometer for Space and Airborne Applications

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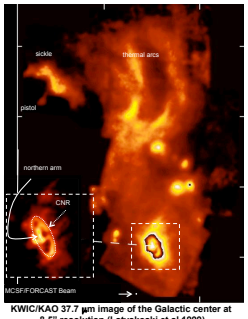
Science Driver I – The Galactic Center

- Radio arcs
- Sickle/pistol thermal radio features
- Sgr A West region
  - Circum-nuclear ring
  - Mini-spiral
- Map in [SiII] (35 μm), [SIII] (33 μm), [NeIII] (36 μm), and [OIV] (26 μm)



KWIC/KAO 37.7 μm image of the Galactic center at 8.5" resolution (Latvakoski et al 1999)

Motivation

- Effective use of 2D arrays
  - Every pixel obtains science data
- High resolving power for small size/mass
  - Finesse ~30, mirror spacing < 2 cm, & R ~ 40000
- Absolute registry between pixels on the sky
  - Efficient mapping
- Insensitive to pointing/seeing
  - Exact source location unnecessary
  - Works at the diffraction limit w/o worries of light loss due to grating entrance slit
- Selectable resolving power
  - R controlled by mirror spacing
  - Tune for expected line width, ideal for weak lines

Science Driver II – Galaxies

- Star formation process & effects in nearby galaxies
- Observe individual giant molecular clouds & star formation regions
- Obtain physical condition of the gas
  - heating/cooling rates
  - density
  - mass
  - temperature

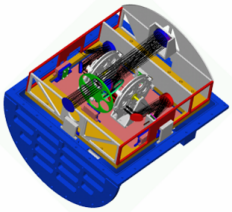

Composite visible and IRAC band image of M51 (Spitzer public web site).

Goal

- Design, construct, test & deploy a miniature, cryogenic, tunable Fabry-Perot interferometer for 25 to 38 microns for FORCAST, a first-light SOFIA instrument
- Develop a miniature, low power, high accuracy, long drive, cryogenic linear actuator to enable the MCSF

FORCAST

- Dual-Channel 256x256 Camera w/ Si BIB arrays
  - 5-25 μm with Si:As array
  - 25-38 μm with Si:Sb array
- 0.75 arcsec/pixel giving 3.2×3.2 arcmin FOV
- Selectable Filters in 5-38 μm range

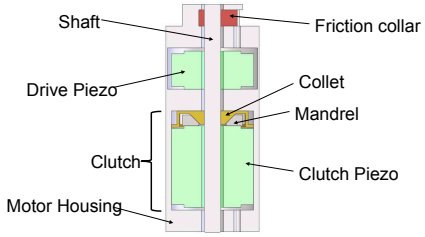


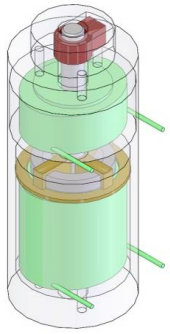
Specifications for the Linear Actuator and the MCSF

- 25 mm clear aperture
- Minimum Tunability (Travel Range)
  - 5 μm for a typical scan (8x Δd) where Δd = resolution element in physical space
  - 83 μm for [SIII] & [NeIII] lines in 66th order, but want to change R
  - 1.4 mm to double R at 35 μm, goal of 5 mm
- Minimum Mirror Parallelism
  - 150 nm = Δd / 4
- Minimum Resolution
  - Required: 120 nm
  - Goal: 60 nm = Δd / 10
- Spatial constraints (set by FORCAST filter wheel)
  - 63 mm diameter, 40 mm thickness (MCSF)
  - Diameter < 20 mm, height < 35 mm (LA)
- Operate in a vacuum at 4K
- Speed
  - ~10 μm/sec, > 99% scanning efficiency
- Maximum Load
  - 5 N, overcome return spring force & ring mass
- Hold position on power off

Linear Actuator Design

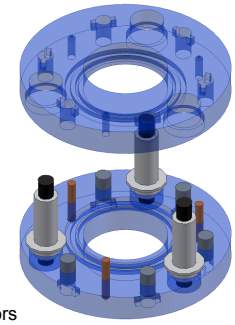
- Piezoelectric Clutch Driven (PCD) motor
  - Uses two piezoelectric stacks with central bore (for displacement shaft to pass thru)
  - One stack actuates a clutch, grabbing/releasing shaft
  - Second stack pushes clutch against resistance of motor housing (providing spring-back)
  - "Ratcheting" action provides large travel
  - Meets or exceeds all linear actuator specifications





Nominal MCSF Design

- Bottom ring (magnetic stainless steel)
  - fixed to FORCAST through magnets
- Top ring
  - Sits on actuators
  - Supported by sliding pins which also counteract shear forces on unit
- 3 actuators
  - Spectral tuning
  - Parallelizing
- 6 springs
  - Hold top and bottom rings together
  - Provide restoring force against actuators



Current Status – PCD Motor

- Virtual testing in SolidWorks Simulation
- Test dewar ready for key-element testing