A Silicon and KRS-5 Grism Suite for FORCAST on SOFIA

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\textbf{Abstract}

We have designed and fabricated a suite of grisms for use in FORCAST, a mid-infrared camera scheduled as a first light instrument on SOFIA. The grism suite gives SOFIA a new capability: low and moderate resolution spectroscopy from 5-37\(\mu\)m, without the addition of a new instrument. We fabricated four silicon (\(n=3.44\)) grisms using photolithographic techniques and purchased two additional mechanically ruled KRS-5 (\(n=2.3\)) grisms. One pair of silicon grisms permits observations of the 5-8\(\mu\)m band with a long slit at resolving power (R) of ~200, or in a cross-dispersed mode at R=1200. In the 8-14\(\mu\)m region, where silicon absorbs heavily, the KRS-5 grisms will provide the spectroscopic capability at predicted resolving powers of 300 and 800 in long-slit and cross-dispersed mode, respectively. The remaining two silicon grisms cover 17-37\(\mu\)m at resolving powers of 140 and 250. We have thoroughly tested the silicon grisms in the laboratory, measuring efficiencies in transmission at 1.4-1.8\(\mu\)m. We report on these measurements as well as on cryogenic performance tests of the silicon and KRS-5 devices after installation in FORCAST.

\textbf{Wavelength Calibration}:

For the silicon grisms, one way to determine a wavelength calibration is to use water vapor emission lines. The wavelength calibration for G1, G1\(\times\)G2, G5, and G6 was determined using the ATRAN model of telluric (mostly water vapor) lines smoothed to the specified resolution of each grism. A dewar of liquid nitrogen (LN2) was placed in the field of view of the camera. A path length of about 1m of room-temperature water-vapor separated the camera window from the LN2 surface. The much warmer water vapor is seen in emission against the 77 K blackbody of the LN2. Water vapor emission lines. The wavelength calibration for G1, G1\(\times\)G2, G5, and G6 was determined using the ATRAN model of telluric (mostly water vapor) lines smoothed to the specified resolution of each grism. A dewar of liquid nitrogen (LN2) was placed in the field of view of the camera. A path length of about 1m of room-temperature water-vapor separated the camera window from the LN2 surface. The much warmer water vapor is seen in emission against the 77 K blackbody of the LN2.

\textbf{Spectral Resolution}:

Measuring the FWHM of unresolved water lines yielded resolutions of ~250 and ~1400 for grisms 1 and 2. Resolution measurements were not possible for grisms 3 and 4 since none of the polystyrene absorption lines are narrow enough to be unresolved. Grisms 5 and 6 show resolving powers of 185 and 265, respectively.

\textbf{Anti-Reflection Coating}:

The entrance faces of Grisms 1 and 2 have been coated with a broad-band anti-reflection coating to reduce polystyrene and channel surface losses at the 1.4-1.8\(\mu\)m bands. Grisms 3 and 4 were coated with a broad-band anti-reflection coating already applied to the entrance faces.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|c|}
\hline
Grism & Material & Physical characteristics & Wavelength band & Design R & Measured R & Measured Efficiency at 1.4-1.8\(\mu\)m \\
\hline
1 & Si & \(\sigma=25\mu\)m, \(8=6.16\) & 5-8\(\mu\)m & 3''x2'' & 200 & 225 & 40\pm3\% \\
2 & Si & \(\sigma=87\mu\)m, \(8=32.6\) & 5-8\(\mu\)m & 2''x15'' & 1200 & 1400 & - \\
3 & KRS-5 & \(\sigma=130\mu\)m, \(8=36.8\) & 8.1-13.7\(\mu\)m & 3''x2'' & 300 & - & - \\
4 & KRS-5 & \(\sigma=87\mu\)m, \(8=6.16\) & 17.1-28.1\(\mu\)m & 2''x15'' & 800 & - & - \\
5 & Si & \(\sigma=87\mu\)m, \(8=6.16\) & 17.1-28.1\(\mu\)m & 3''x2'' & 140 & 185 & 39\pm3\% \\
6 & Si & \(\sigma=142\mu\)m, \(8=10.7\) & 28.7-40.0\(\mu\)m & 3''x3'' & 250 & 265 & 41\pm3\% \\
\hline
\end{tabular}
\caption{FORCAST grism suite. The physical characteristics in column 3 are groove spacing (\(\sigma\)), prism angle (\(8\)), and order in which grism will operate (\(m\)).}
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