SCUBA-2 Spectrometer Project

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Summary

This document outlines the progress made in the SCUBA-2 spectrometer project since work started in September, through the end of 2002. An FTS system has been selected over other spectrometer options, the thermal loading characteristics have been modeled, and the mechanical configuration and mounting location for the instrument have been proposed. Work has started on the optical modeling and software development.

Spectrometer Selection

Discussions concerning the various spectrometer options for SCUBA-2 were held during the SPIE Instrumentation in Astronomy conference in Hawaii and a recent SPIRE meeting in Cardiff. The consensus was that an ambient temperature FTS was the preferred solution. The following points summarize the key results:

- Cold FP inside the main cryostat is rejected on grounds of risk to the whole system
- Cold external FP significantly de-loads the detectors, but this gain cannot be realized because the detectors are designed for a much higher background loading and themselves become the limiting components.
- FTS loading is not excessive, and the resulting photon NEP is expected to be reasonably well matched to the designed SCUBA-2 detector NEP
- FTS efficiency of 43.7% is very similar to a dual FP system (such as SPIFI which achieves efficiencies between 36% and 64%)
- An FTS plays to the proven strengths of the Lethbridge team and exploits the synergy with the SPIRE project
- An FTS, with its broad spectral coverage, played a key role in troubleshooting and commissioning SCUBA; having one available during the commissioning of SCUBA-2 would be a big asset.

More information can be found at http://research.uleth.ca/scuba2/documents/reports/

CAD Modeling

Due to the large size of the SCUBA-2 beam at all accessible points in the path, the FTS will require large optics and will occupy a large volume. CAD modeling has been carried out to ensure that the FTS can fit in the space left after the SCUBA-2 optics have been mounted to the telescope. Initally, the Nasmyth platform was proposed as the mounting location, however, the space between the elevation bearing and mirror N1 provides a smaller beam diameter and better accessibility. A physical envelope for the FTS was given to the JAC engineering team to assess the feasibility of mounting the FTS in the support structure for

N1. A schematic of the FTS at the proposed location is shown below (the support structure for N1 is not yet designed).

Optical Modeling

The SCUBA-2 FTS will have a Mach-Zehnder configuration, and be conceptually similar to both the U of L FTS and the SPIRE instrument. A paper describing this type of spectrometer can be found at http://home.uleth.ca/phy/naylor/pdf/SPIE_Hawaii_MZFTS.pdf

The beam at the bearing is not ideal, but it is as good as it gets. Due size of the beam at this location, and the constraint imposed by the size of available beamsplitters, only a section of the full SCUBA-2 beam (at least one full sub-array) will pass through the FTS. The optics would be simplified by picking off an area in the center of the field of view, rather than a quadrant, although this would carry a data analysis penalty. Even without taking the full SCUBA-2 beam, the FTS optics will need to be ~ 300 mm diameter. In order to pick off the beam, feed it through the FTS, and pass it back to SCUBA in its original state, the FTS pickoff mirrors will have complex surfaces, and the system will require detailed optical modeling to ensure minimal image distortion at the SCUBA-2 detector plane. Modeling an FTS within the already complex SCUBA-2 optical system is a non-trivial task, and will likely take until the summer of 2003 to complete. Zemax was chosen as the optical design package for compatibility with the ATC and Cardiff systems.

Thermal Loading and Noise Analysis

During the spectrometer selection process, radiative transfer modeling was performed for the potential SCUBA-2 spectrometer systems in order to determine the effect on detector loading and optical noise. The results are summarized here, for 0.5mm and 1 mm precipitable water vapor levels at the JCMT:

		0.5mm PWV		1mm PWV	
	System Transmission	Total Loading (pW)	Overall NEP (10^{-17} W/ sqrt Hz)	Total Loading (pW)	Overall NEP (10^{-17} W/ sqrt Hz)
no spectrometer	52%	7.7	6.9	9.5	7.5
external cold FP	0.0002%	1.9	3.4	1.9	3.4
FTS w/ LN2 BB	23%	11.5	8.5	12.3	8.7
FTS w/ warm BB	23%	25.3	14.3	26.1	14.4

More detailed analysis for the FTS system can be found at:
http://research.uleth.ca/scuba2/documents/analysis/

The loading produced by the warm FTS should not represent a problem for the SCUBA-2 detectors, however, there may be problems maintaining the SQUID flux-locked-loop due to the large and rapid signal swings as the FTS scans through the zero path difference point. This issue should be resolvable by using a variable scan rate, or clever signal cancellation using a blackbody source in the second input beam.

The U of L group has recently produced an accurate atmospheric model which will soon be included in the FTS radiative transfer model.

Software

Software development will be the largest task in the FTS project. Prototyping of the data analysis pipeline and GUI will be carried out in IDL; the routines will later be transcribed to a language supported by the JAC. The U of L group is currently developing a data pipeline for the SPIRE FTS, and there will be significant overlap in the software development for the two projects. Unfortunately, the SCUBA-2 software design is not nearly mature, and there are many details to work out for integrating FTS processing in the pipeline. A framework for this interface should be developed before the SCUBA-2 software PDR. The algorithms that don't already exist in packages like SURF need to be written before the software CDR stage.

Provided that the Stare mode is realized, the FTS software should be relatively straight forward to implement. The Real Time Sequencer controls the data acquisition system, with strobes every 200. The FTS would provide a table position index at each strobe, and this position would be included in the data header for each frame. The JAC pipeline would handle the quick-look and actual FT calculations. It is unclear how flatfielding would be accomplished.

Hiring

We have budgeted for a full-time software engineer for the duration of the project, as well as 3 years of Co-Op student effort for the software development, including the data pipeline, interface with JAC software, and GUI. The position for the main software engineer will be advertised in the March. As there will be effort required to integrate the FTS software with the SCUBA-2 pipeline and JAC systems, the ads will be targeted to individuals with experience with the JAC software packages.

Successes

- Demonstrated that FTS will be compatible with the dynamic range and loading capability of the SCUBA-2 detectors.
- Determined that a minimum ¼ array FTS could in principle be built in the available space, and with currently available beamsplitters.

Opportunities

- Investigating sources for large diamond turned mirrors.
- Investigating acquisition of a small detector array for hardware testing and software prototyping.

Failures

- None to report

Threats

- Modeling will need to be completed to determine if the zero path difference signal fluctuations will cause problems for individual pixels, or across the arrays.