Gazing into the universe

FT-spectrometers from ABB in astronomical telescopes

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Often, innovation comes from applying a technology which has proved itself in one discipline, to a completely different field. Sometimes the experience gained in such applications flows back to augment and open new possibilities in the original field. This is the case for Fourier Transform Spectroscopy (FTS) which was developed for astronomical telescopes in the 60ies but found a far broader market in chemical monitoring in industrial processes. The enhanced technology is still equipping high-tech telescopes – where it is revealing the secrets of matter in the furthest reaches of the universe.

In 1998–1999 an international effort worked on defining the best instrumentation for the James Webb Space Telescope (JWST), which is scheduled to be launched in 2012 as successor to the well-known Hubble Space Telescope. ABB Bomem took an active part in this endeavour by presenting an astronomic imaging adaptation of their FTS (Fourier Transform Spectroscope) to the NASA/ESA/CSA consortium. This allowed astronomers to recognise the great potential of IFTS (Imaging FTS) and the experience of ABB Bomem in the control of such a precise clocking device. In late 2000, following on from this proposal, Laval University and ABB launched a joint effort to design an operational ground instrument for the 1.6 meter telescope of the Mégantic observatory in Canada. The instrument was first tested on the telescope in February 2004. In terms of the number of pixels (1.7 M) and the field of view (12 arc minutes), this IFTS is by far the largest ever used on a ground telescope and the only one to operate in the visible band. ABB is the integrator of the complete instrument, which includes an innovative step-scan FTS module, two CCD (charge-coupled device) cameras, two lens assemblies for the output optics and a collimating lens set. The instrument's overall dimensions are 133 × 80 × 80 cm and its weight is approximately 110 kg.

The design goal of this instrument is to maximize throughput and transmission to help astronomers collect as many photons as possible. The instrument operates in the 350–950 nm band to match the sensitivity of the two 1340 × 1300 pixel CCD cameras at the interferometer[1] output ports. Because the interference occurs at visible wavelengths, a mechanical control is required in the nanometer range. A piezo-based frictionless translation stage has been designed to control the angle and position of the moving three-inch mirror of the interferometer. A sophisticated laser-based metrology system optically reads the position and angle of the mirror, 8000 times per second. A dedicated computer determines corrections to apply to the piezo translators in order to stabilize the fringe images and maximize the contrast recorded on the CCDs.

The dual output port design (2 CCDs) is achieved using flat mirrors and by inserting the science beam off-axis. This is the first implementation of this kind described in literature. The arrangement reduces the number of reflections encountered by the science beam. The beam splitter has a sophisticated multilayer dielectric coating that strongly modulates light in the specified waveband without contributing undesired absorption. The seven lenses used for collimating and re-imaging enable the fulfilment of the light-collimation requirement, and also the sub arc-second panchromatic point spread function at the image plane. About a million independent spectra can be collected from distinct scene elements. This is more, by a factor of about a thousand, than is offered by traditional multi-object/imaging spectrometers. The total system transmittance reaches over 60 percent (30 percent per CCD) at 500 nm, thanks to the use of a detector with 90 percent quantum efficiency. This is a value that is unmatched by any other spectrometer. The cameras are cooled with liquid nitrogen, enabling a very low readout noise (3 electrons) and hence a high sensitivity. This instrument can literally count photons.

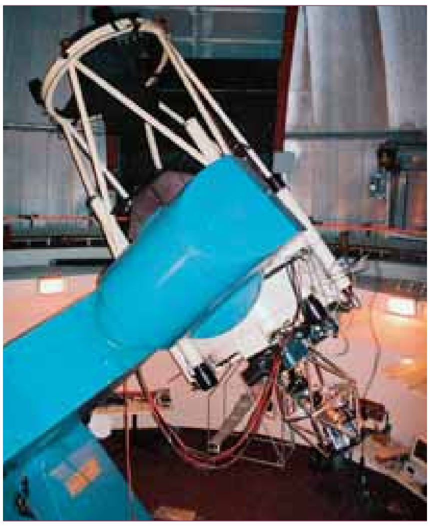
The instrument is controlled remotely using a LabView application. The user has full control over the following parameters of the scan:

- Step-size (related to spectral range)
- Number of steps (related to spectral resolution)
- Integration time per step (adaptability to scene intensity)
- Acquisition order of interferogram points (ability to manage bad sky conditions)
- Camera readout rates (1.8 sec or 18 sec influencing noise level)

The wealth of data from this IFTS comes at the cost of measurement time. A typical cube acquisition[2] runs from minutes to hours, depending on the parameters selected. However, as astronomers are accustomed to sitting and waiting for light to shine into their instruments, this is no impediment. A data reduction software package was developed at Laval University.

The instrument is still under commissioning at the Mégantic telescope 1. It is foreseen that it will be made available to the astronomers in mid 2006 for use on any type of science program. ABB hopes the interest raised in the community from the science papers published using results from this instrument will bring the opportunity to build other units for the current generation of large ground based telescope (>10 m) or future space based facilities.

1 The Mégantic telescope in Canada uses an Imaging Fourier Transform Spectroscope from ABB.



Nebulae

The Helix Nebula (main picture) is a cloud of gas expelled and illuminated by the dying star at its center. Picture taken by Hubble Telescope (NASA, STSCI).

The inset on the left shows the Dumbell Nebula (M27). This picture was recently made with the described instrument.

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Footnotes

[1] See textbox "Principle of the interferometer" on page 53

[2] See textbox "Datacubes" on page 49