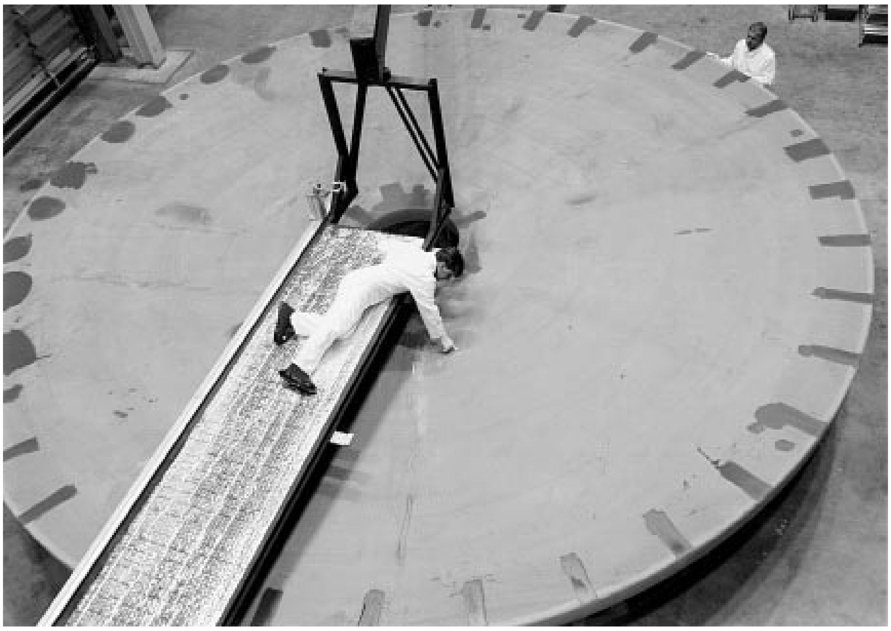

Figure 4: Preparation for the measurement of residual stresses (birefringense measurements).

areas exceed them by a substantial factor (Table 1). Residual stresses were found to be extremely low (Fig. 4). The contract was executed in time, within specifications and budget.

All four blanks are now at REOSC; two of them have been completely processed into finished mirror assemblies, tested and found to comply with the specifications (Fig. 5). They are now in storage prior to their departure to Chile. The third one is under polishing (currently about half a wave RMS wavefront error) and should be completed during the first quarter of 1997. The last one will remain in storage until early 1998, when REOSC will mount axial interfaces and start grinding.

In the light of the achievements realised so far, it is particularly interesting to review the documentation of the mid-80's, when the currently built telescopes (Keck, Gemini, Subaru, LBT, SST – renamed Hobby/Eberly) were in their conceptual design phase. At that time, possible diameters for monolithic mirrors rapidly narrowed to the 8-m range, with the argument that the extrapolation of the mirror technology to the 8-m range represented an ambitious but realistic step beyond the 4-m-class telescopes of the 60's–70's. Key issues were the technology for the blank production, but also the difficulty of handling very large mirrors. The developments undertaken and the results obtained by SCHOTT may lead to the impression that larger monolithic mirrors might be theoretically feasible, e.g. in the 10–12-m range. This may be true from a pure technological point of view, but the experience gathered so far indicates that there would most likely be a noticeable discontinuity in the cost-scaling law above a limit which looms around 8.4 m, essentially set by handling and above all transport constraints.

Philippe Dierickx
e-mail: pdierick@eso.org

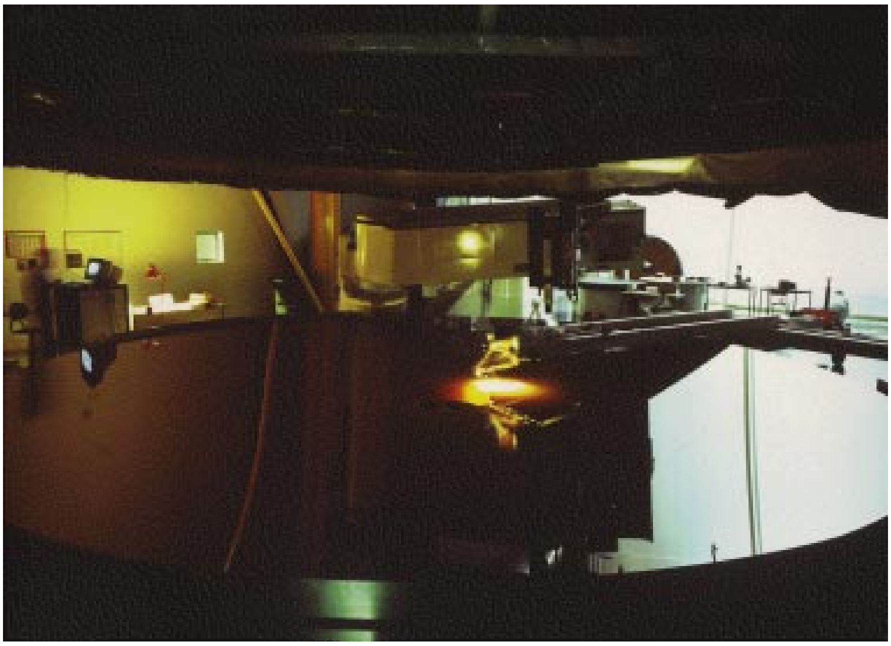

Figure 5: Primary Mirror undergoing acceptance tests at REOSC.

ISAAC Takes Shape

J.-L. LIZON, Integration Group, Instrumentation Division, ESO, Garching

Description

ISAAC (Infrared Spectrometer and Array Camera) is one of the two VLT instruments being developed by ESO and is planned to be installed at one of the UT1 Nasmyth foci in 1998. Its scientific capabilities include both 1–5 μm imaging over a field of up to 2.5 × 2.5 arcmin and long-slit spectroscopy at nominal resolving powers of ~500 and ~5000. In order to optimise its performance over the full wavelength range, it contains two separate cameras optimised for the 1–2.5 μm and 2–5 μm regions which can be used to directly image either the telescope focal plane or the intermediate spectrum produced by a grating spectrometer. Further details of the instrument design and performance can be found under Very Large Telescope (VLT) Observatory on ESO's WWW Home Page.

ISAAC Integration and First Tests

Our main purpose here is to report on the status of the instrument integration and results of the first tests performed in Garching. As can be seen from the ac-

▲ *Figure 1: One of the two ISAAC cameras comprising the array detector unit (not shown); the objective wheel and two filter wheels. In common with most moving functions, the wheels are driven by 5-phase stepper motors and spring loaded worm gears acting on the large toothed rings.*

Figure 2: The partly assembled instrument showing the cryogenic optical assembly with one of the cameras mounted (only the detector unit visible at the top right) provisionally supported in the vacuum vessel.

companying photographs, the scientific requirements of achieving excellent image quality over a moderately large field at an 8-m telescope leads to a rather large instrument. This is a general feature of the major VLT instruments. What makes ISAAC a particular challenge, however, is that its complete optical and detector assemblies must operate at cryogenic temperatures and under vacuum. This poses a range of difficult design and integration problems. Although designed to be as compact as possible (e.g. by employing a novel spectrometer collimator consisting of 3 off-axis hyperbolic, diamond-turned mirrors) the vacuum tank housing the instrument is still ~1.5 m in diameter. The cryogenically cooled optical assembly is only slightly smaller and weighs ~ 300 kg. Although shrinking significantly on cool-down it must not distort the optical alignment and must be supported such that it meets stringent flexure requirements but with minimum thermal conductivity to the vacuum vessel. Its various motor-driven moving functions must also operate reliably and with high precision but without conventional lubrication and with a minimum of power dissipation. Despite its large size and weight, the cryogenic system has been designed to achieve cooling times which are comparable to many much smaller instruments currently in operation. Nevertheless, every modification required during the integration phase carries a large time penalty resulting from the need to close, evacuate, cool, warm-up and open the instrument.

The accompanying photographs illustrate several phases in the integration process. Figure 1. shows one of the two camera assemblies comprising the infrared array detector (up to 1024 × 1024 pixel format); objective wheel for changing the magnification and two filter/polariser wheels. The wheels are driven by 5-phase stepper motors and worm gears acting on the outer toothed rings. As with all ISAAC functions, the cameras have been assembled and performance tested as units in a separate, rotatable, cryogenic test chamber in order to minimise problems at the system integration level. Figure 2 shows the cast aluminium optical support structure mounted in the vacuum vessel and with some of the functions installed. At the top right, one of the detector units can be seen but the camera itself is buried inside the housing. The supporting system is provisional – the whole optical assembly is finally supported by two stainless steel spiders attached to the front and back which allow for the instrument shrinkage and are attached close to the centre of gravity to minimise flexure. Figure 3 shows the integration at a more advanced stage with the installation of additional functions including the large slit/mask wheel prominent at the front. Also visible are the two closed-cycle coolers at the top and bottom which maintain the instrument at ~ 80 K and the infrared detectors at temperatures down to ~ 30 K. Figure 4 is a rear view of the complete instrument enclosed in its vacuum vessel. The unit to the right is the permanently-mounted magnetic bearing, turbo-molecular pump used to evacuate the vessel. The two closed-cycle coolers are mounted on bellows and supported by the long bar to minimise vibrations. Figure 5 shows the instrument from the front during optical testing through its entrance window with a laser interferometer. In the background can be seen the instrument attachment flange mounted on the Nasmyth adapter simulator used for flexure and other tests. Partially visible on the right is the cryogenic test facility used to test the individual functions.

Some Early Results

So far the tests of ISAAC seem to confirm that its overall design is sound. After only a few thermal cycles, evacuation of the vessel already takes less than 15 hours and is expected to become progressively faster as the residual outgassing decreases. The cryogenic optical assembly cools to 80 K in only 26 hours using its integrated, continuous-flow liquid-nitrogen pre-cooling system and can be warmed up in less than 12 hours with the instrument-mounted heaters. Most importantly, the optics not only survives cooling but its optical quality remains essentially unchanged relative to room temperature. This is a great relief, despite our confidence in the design, considering that the spectrometer chain includes a large-lens collimator (16 cm diameter BaF_2), the three-mirror collimator, grating mount, a 4-lens objective and several diamond-turned aluminium mirrors. The spectrometer collimator was of

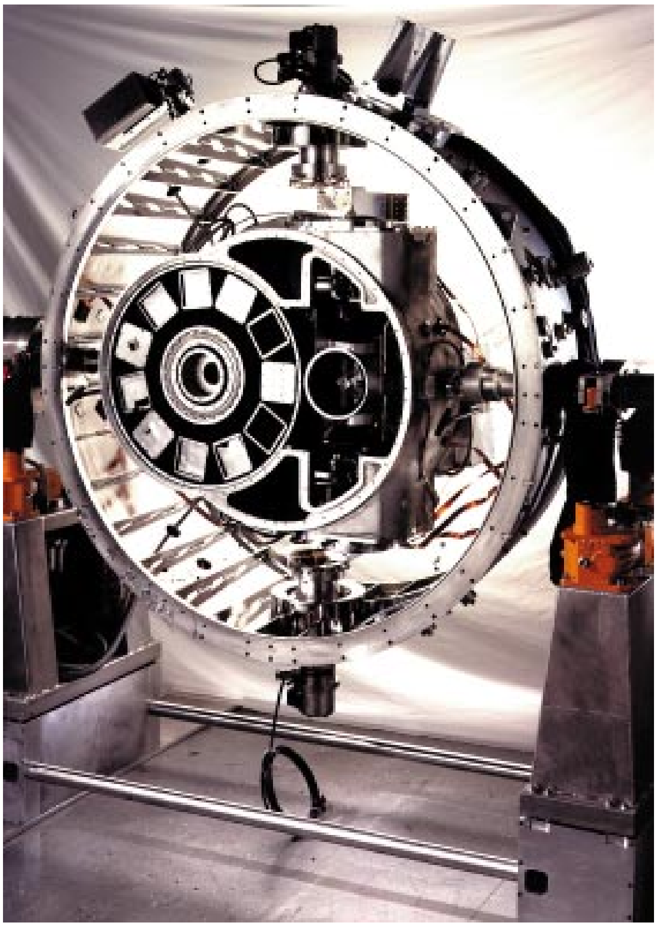

Figure 3: Almost completely assembled instrument with the large slit/mask wheel clearly visible at the front.

▲ *Figure 4: Rear view of ISAAC fully integrated in its vacuum vessel. The closed-cycle coolers at the top and bottom are mounted on bellows and connected by the long bar to minimise vibrations. Also visible to the right is the permanently mounted magnetic bearing turbomolecular pump used to evacuate the vessel.*

particular concern because its 3 mirrors are attached to and hence sensitive to any thermal distortion of the large optical support structure. The supporting spiders also perform as designed to provide rigidity of the complete instrument at the few µm level when cold. All of the moving functions operate smoothly and the vibrations introduced by the closed-cycle coolers are at an acceptable level, not only for the instrument itself but also to meet the more demanding requirements imposed by the VLTI. Readers with experience in building cryogenic instruments would be surprised if there had been no problems at all. In fact, achieving some of the above has required considerable effort, and not all aspects are yet fully acceptable. In particular, maintaining a low enough operating temperature using the closed-cycle coolers alone has proved difficult. It is now clear that this was due both to reduced cooling power when operating two coolers over long gas lines from a single compressor and additional parasitic heat loads. Most of the additional heat load has now been traced to unplanned thermal contacts, which have been removed, and a higher than expected emissivity of the radiation shield which has been temporarily solved using superinsulation. In parallel, the first detector system and control software have been prepared and are almost ready to be installed for the first complete system test during the next few weeks.

Acknowledgements

Although only the integration aspects have been illustrated here, this development would not have been possible without the combined efforts of the ISAAC team which is headed by Alan Moorwood as PI and includes staff in the Instrumentation, VLT and Data Management Divisions. I am particularly grateful to Armin Silber and Ralf Büttinghaus for their help with the integration and to Ralf for actually manufacturing many of the mechanical pieces. Credit for the optical performance reported here is due largely to the efforts of Bernard Delabre and Anton van Dijsseldonk while Gotthard Huster was responsible for most of the mechanical design.

J.-L. Lizon
e-mail: jlizon@eso.org

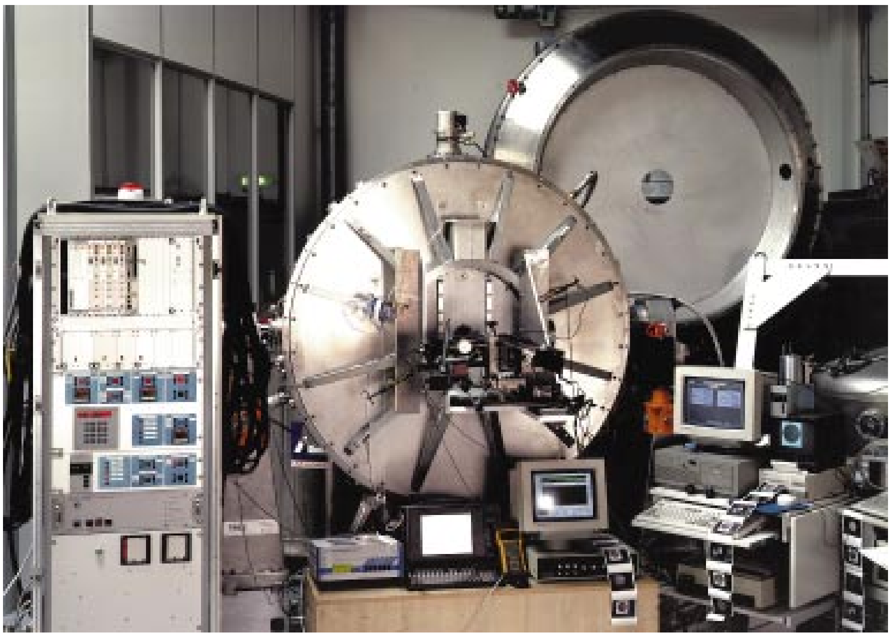

Figure 5: Front view of ISAAC during optical testing through the entrance window with a laser interferometer. In the background can be seen the ISAAC adapter flange mounted on the Nasmyth simulator used for flexure and other tests. Partly visible to the right is the cryogenic test facility used for testing the individual functions.