azimuth box to measure azimuth rotation and was later fixed to the centrepiece in order to measure altitude rotation.

The OGE measures in respect to inertial space, while the NTT encoders measure in respect to altitude/azimuth coordinates of the earth frame. Because of this basic difference in operation, several special effects were detected:

1. Stressing of the azimuth bearing support ring. When the telescope starts to move from a stand-still position, the telescope is already moving before the NTT encoder measures a rotation. This is due to the friction in the radial bearing of the azimuth axis, which is also the mounting location of the NTT encoder.
2. Sag of structural parts of the centerpiece of the NTT according to the altitude position.
3. Minor nonlinearities of the NTT encoders in the sub arcsec range.
4. Details of the control loop behaviour.

The preliminary evaluation of the test data gave the following characteristics:

Pointing accuracy: Azimuth axis: < 0.7 arcsec rms
Altitude axis: < 1 arcsec rms

Tracking accuracy: < 0.1 arcsec rms over a time of 30 seconds

Resolution: $< 3\times10^{-4}$ arcsec at a read-out rate of 10 Hz

Bandwidth: up to 120 Hz (adjustable by software)

No temperature compensation had to be applied.

In gyro terms the data are as follows:

Bias stability: $< 2\times10^{-3}$ degrees/hour

Scale factor stability: < 1 ppm

Random walk coefficient: $< 5\times10^{-4}$ degrees/$\sqrt{\text{hour}}$.

The high resolution and bandwidth make the OGE an excellent device for telescope tracking. Having fiber optic gyros mounted on the telescope tube, the rotation rate has to be zero during tracking for alt-azimuth mounted telescopes as well as for equatorial mounted telescopes. However, the intrinsic integration principle and drift require the use of an initialization reference and an autoguider.

The installation of an OGE is easy because it does not need to be mounted in the telescope axis and there are no tight mechanical tolerances to be respected.

On an equatorial mounted telescope, the application is even easier because no coordinate transformation is needed: If one OGE is mounted on the alpha and another one on the delta axis, they see an inertial rate of zero during tracking. This also means that, in this case, the tracking performance is not dependent on a pointing model: the OGEs drive the motors in such a way that the inertial rate becomes zero.

The test campaign proved that this device is also quite useful for calibrating existing encoders and for analysing existing telescope control loops and structures.

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References

[1] F. Merkle and M. Ravensbergen: *The Messenger* No. **65**, Sept. 1991.
[2] W. Schröder et al. (1991): Proc. SPIE 1585.

Infrared Astronomy with Arrays: the Next Generation

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The title is that of a conference held at UCLA in July 1993 at which approximately 250 participants experienced a feast of 73 papers and 120 posters covering both recent astrophysical results and future prospects for the next generation of infrared array instruments on large ground-based telescopes and in space. Although it was a very exciting meeting both scientifically and technically with many highlights, the purpose of this article is not to review the conference (to be published as a book by Kluwer and edited by Ian McLean) but to draw attention to developments in the field of infrared array detectors reported there which are of great interest for both planned and future VLT instruments. Partly because the conference was in California, the infrared detector manufacturers were represented in force to present their products and solicit feedback from users on the performance of current arrays and their future requirements in a special "meet the industry" evening session. Such sessions have become a regular feature of specialist infrared conferences, and this one really demonstrated the extensive cooperation which has developed between astronomers and industry during the last few years and the remarkable progress made in the development/optimization of arrays for infrared astronomy.

Based on the quantity and quality of the scientific results presented, the standard in the near infrared (1–2.5 μm) region has clearly been set during the last few years by the 256×256 Hg:Cd:Te NICMOS3 array developed for the HST instrument with whose name it has become synonymous (and whose home was visited by many of the participants on an oversubscribed tour organized by the Rockwell International Science Center). This is the array installed in IRAC2 at the 2.2-m telescope on La Silla and currently baselined for the short wavelength channels of the ISAAC (see *The Messenger*, 70, 10) and CONICA (*The Messenger*, 67, 17) instruments for the ESO VLT. With its relatively short long wavelength cut-off this array yields extremely low dark current (~0.1 e/s) and read noise (~20 e) at comfortable operating temperatures ~70K. Results at the conference, however, revealed the strong competition it now faces from the new SBRC 256×256 InSb array, successor to their famous 58×62 device, which is sensitive out to 5 μm and has been baselined for the long wavelength channels of ISAAC and CONICA. Somewhat unexpectedly, the first tests of these arrays have shown that they can also compete with the Hg:Cd:Te arrays with regard to dark current and noise, albeit at less comfortable temperatures (~30K) and with much more stringent requirements on the instrumental background due to their longer cut-off wavelength. They also yield quantum efficiencies >0.8 which are higher than the Hg:Cd:Te arrays at the short wavelengths and do not appear to suffer from the persistence and "glow" problems of these arrays under extremely low background conditions. Among the first instruments equipped with such an array is the Caltech infrared camera for the Keck telescope which has already achieved a 1σ K′ (2.1 μm) limit of 22 mag./sq. arcsec in 20s of integration time. Unfortunately, the well capacities of the first devices are rather low (~$2 \cdot 10^5$e) for ground-based L (3.8 μm) and M (4.8 μm) broadband imaging. At ESO, however, we are currently preparing to test an engineering array of this type and expect delivery early next year of a science grade array with higher well capacity if current experiments with higher doping at SBRC are successful. Cincinnati Electronics also presented their new 256×256 InSb array which yields higher well capacities of ~10^6e at the expense of higher dark current and read noise and could be of great interest for long-wavelength imaging. The big news, however, was that both Rockwell and SBRC have now started development of 1024×1024 arrays, i.e. jumping the previously anticipated next step in format. Both plan to utilize four quadrant read-out chips so that 512×512 arrays should also be available if required and offer a fallback if yield of the full arrays proves to be a major problem. Both companies appear to be more concerned, in fact, by yield (and hence cost) than technical performance aspects although Rockwell plan a concerted attack on the persistence problem and hope also to increase quantum efficiency and reduce the read noise of the new devices to ~5e. The prospect now, therefore, is not only of much larger formats but also improved sensitivity and hence a considerable overall performance gain. One of the VLT infrared instruments still in the definition phase at ESO – the cryogenic infrared echelle spectrometer – actually requires arrays of this size for a reasonable echelle format and will clearly profit from any improvement in noise performance as such an instrument should be detector limited over much of its wavelength range. Technically, it is also not too late to plan for the use of these larger format arrays in ISAAC and CONICA. Although the present 256×256 arrays were baselined even before these arrays became commercially available, the optical designs of both instruments were specified to accommodate 512×512 arrays in anticipation of future developments. An expansion to 1024×1024 now appears possible without major optomechanical changes if and when they become available.

Considerable progress was also reported on the development of longer wavelength arrays which cover the 10 and 20 μm atmospheric windows and are of interest for the VLT mid-infrared imager/spectrometer for which ESO has contracted a Phase A study to a consortium of institutes led by the Service d'Astrophysique, Saclay (see *The Messenger*, 73, 8). Performance of the high well capacity (~10^7e) 64×64 Ga:Si photoconductor array developed by LETI/LIR in France for ground-based use in the 10 μm window was demonstrated to good effect by an image of the β Pic disk obtained by P.O. Lagage using TIMMI at the ESO 3.6-m and voted one of the conference scientific highlights by Mark Morris in his closing summary. The follow-on development of this device to a format of 128×192 pixels being managed by INSU and with ESO participation was also presented. A novel feature of this array, appreciated by many participants, is the possibility of switching between high and low values of the charge capacity in order to optimize its performance under different background conditions (e.g. imaging and spectroscopy). Both SBRC and Rockwell have also developed low-noise, high-capacity (10^7e), As:Si IBC/BIB (Impurity Blocked Conduction/Blocked Impurity Band) arrays with formats up to 256×256 which are sensitive throughout the 10 and 20 μm windows although it has yet to be established that such devices can be exported outside the United States. Rockwell also reported progress with As:Si solid-state photomultipliers which have high q.e.'s (~0.7) and are capable of counting single photons with a response time of 50ns. Although the present formats are small (10×10), these devices may be of interest in the future for very low background (e.g. high-resolution spectroscopy) applications and the measurement of fast transient phenomena.

This is obviously an exciting and probably exceptional period in the history of infrared array development. If, as expected, the detectors highlighted here materialize within the next few years, infrared astronomers will have evolved from using noisy single detectors to almost "perfect" arrays of one million pixels within a period of little more than a decade. Coupled with the new instrumental opportunities created and the larger telescopes now under development, they will clearly open the way for the next big step in our exploration of the infrared universe.

Current CCD Projects at ESO and Their Relation to the VLT Instruments

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1. Introduction

The following is a brief description of CCD detectors foreseen to be used with VLT instruments currently under study or design and of the contracts under way to procure them.

In the actual sequence of work, the requirements on the detectors to be used are set in the instrument design phase and this is the starting point for the procurement activities. In this presentation, it is more convenient to describe the various developments now under way and then state their relevance to the different VLT instruments.

Different strategies of procurement are necessary because large CCD detectors for application in advanced astronomical instrumentation are not available as off-the-shelves products. Moreover it is not possible to define a standard CCD device, because the requirements change from instrument to instrument depending on its scientific aim. One can differentiate between the following types of CCDs:

- Well-specified "catalogue products" where a design and manufacturing process already exist and the device is to a basic extent tested at the manufacturer. For large sizes, however, the manufacturing itself still implies a number of risks (e.g. in thinning) thus making the delivery unforeseeable.