HIGHLIGHTS OF IAU SYMPOSIUM No. 167

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1. ARRAY DETECTORS: FROM THE FAR UV TO SUBMILLIMETER WAVELENGTHS

The talks at this IAU Symposium have illustrated the spectacular development which has taken place in the last decade in the field of array detectors for astronomy. Just a few years ago it was possible to speak of two-D detectors for the UV-red wavelength range only. At this meeting we have witnessed presentations on array characteristics from the extreme UV (Bonanno 1995), through the blue-visual range (D'Odorico 1995, Jorden and Oates 1995, Iwert 1995 and Luppino et al. 1995); the infrared 1 to 5 μm window (McLean 1995, Finger et al. 1995, Gilmore et al. 1995, Fazio 1995, Glass et al. 1995 and Ueno et al. 1995); the 10 - 20 μm window (Fazio 1995, Gezari 1995) and finally to an array of bolometers to operate at submillimeter wavelengths (Moseley 1995). Field imaging and spectroscopy are now possible across this entire energy spectrum and some of the first exciting astronomical results obtained with these devices have been presented here.

The infrared region between 1 to 5 μm is the one where the progress has been most impressive. Arrays of 256^2 pixels, InSb-based by SBRC and NICMOS MCT by Rockwell are now in regular operation at different observatories. Still, their operational characteristics are not yet fully investigated (see the presentation by Finger et al. (1995) for a flavor of the present status). Experience with CCDs shows that only by the use by different scientists on different programs can the detector behavior be fully explored and its capabilities well understood. The Shift-and-Add and Weighted SAA techniques to enhance the image quality discussed by Finger et al. (1995) and Ueno et al. (1995), respectively, are examples of potential, added-value applications of infrared detectors. In the spectroscopy field the user experience with the new arrays is even more limited because to our knowledge there are just two spectrometers based on 256^2 detectors which started operation in 1994 (KSPEC of the University of Hawaii and the upgraded CRSP of NOAO), although many are in the construction phase. The two principal suppliers of infrared detectors for astronomy, Rockwell and Santa Barbara Research Corporation, have also announced the availability in 1995 of 1024^2 arrays. First observations with a prototype 1024^2 HgCdTe detector from Rockwell (device name: Hawaii) have been already obtained. If these large arrays become indeed off-the-shelf products in 1995, this can lead in the infrared to the embarrassing situation that astronomers will not be able to fully exploit the capabilities of the new arrays because the development time of a matched cryogenic instrument is at least three years.

2. A SOBER VIEW OF THE STATUS OF CCDs FOR ASTRONOMY

Charged Coupled Devices remain, even in this era of expanding capabilities for infrared detectors, the devices with which the largest fraction of astronomical data are collected at

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ground-based telescopes. In an ideal world, astronomers would like to have for their instruments CCDs with sizes up to a 50 cm^2, pixel sizes from 15 to 50 μm, QE close to 100%, negligible read-out-noise and dark current and, last but not least, affordable prices. It is tantalizing to see that for some of these characteristics we are close to realizing the ultimate goal but there are also areas where progress has been slow. After the disappearance of RCA from the market of manufacturing chips for astronomy it has been difficult to find a stable supplier of high-efficiency CCDs. Tektronix, now SITe, has been the main source of thinned devices in the 512^2 and 1024^2 formats, but progress was slow on the 2048^2 devices. ESO had foreseen the use of a 2048^2 thinned CCD in the 1985 design document of the multi-mode instrument EMMI for the Nasmyth focus of the 3.5-m New Technology Telescope. The instrument was completed and installed in 1990 but the planned detector could be implemented in 1994 only, that is nine years after it was announced as an off-the-shelf device. Clearly one of the reasons for the slow progress by industry has been the lack of investment and coordinated efforts by the scientific community on this crucial component. We should be careful to make sure that this does not happen again on other crucial detector developments.

At the beginning of this decade a new approach to CCD procurement to circumvent both the high cost and the lack of flexibility in the CCD industry was proposed to the astronomical community. In the new scheme the astronomers and engineers responsible for detector definition and procurement actively participate in the chip design using standard CAD packages running on PCs. After the preparation of the corresponding mask, a production run (typically 20 four-inch silicon wafers) is commissioned to a silicon industrial laboratory which acts as a foundry on a best effort basis. J. Geary at the Harvard Smithsonian Center pioneered this approach and has been the main contributor to the design of new chips. Loral South (the former Ford Aerospace) has been the most effective foundry of CCDs for astronomy. The working chips are identified by on-wafer testing, again in collaboration between the final user and the manufacturer. The selected chips are finally packaged and bond-wired. They are however front illuminated devices with a low QE. The subsequent steps, thinning, surface treatment and coating, have also to be subcontracted to a specialized laboratory. M. Lesser of the Steward Observatory of the University of Arizona has set up a well equipped thinning and coating laboratory with the associated testing facilities and has been the most active in this area producing in the last five years a number of chips with very high QE. Many astronomical groups, including ESO, have gone all the way down this route with generally satisfactory results. It has to be remarked however that the quality of the chips produced on this best effort basis has been sometimes disappointing and the thinning process has encountered unexpected difficulties.

A few years down the road, one can recognize that the new approach has opened the way to new ideas and provided a number of devices which found useful applications at the telescopes, but has yet to prove itself as the reliable source of a significant number of large, high quality CCDs which the astronomical community needs. We certainly hope that the success rate will increase in the future but the community should also make sure that the industrial suppliers maintain an interest in this field. A personal view of the status of some key issues on CCDs as emerged from the presentations and discussions at this meeting is given below.

2.1 CCD Size and QE

In the last few years we have often heard about a coming boom in the size of CCDs which could be used for astronomy. The CCD mosaic projects now in operation (Macho, MOCAM and the Tokyo Camera, just to quote the ones presented here) use however front illuminated CCDs of low QE. The somewhat disappointing truth is that if you want to buy a 2048^2 high efficiency CCD off the shelf, there does not exist a single manufacturer which will accept the order and guarantee the specifications (SITe). A large number of dedicated efforts are "almost" there. M. Lesser is working intensively on the thinning of three-side buttable 2048^2 CCDs produced by Loral South and has been already successful on a few devices of comparable size. Stover et al. (1995) have presented here the work on 4096 x 2048 devices produced by Orbit which he hopes to thin in a newly set-up detector lab at Lick Observatory. ESO has a running contract with Thomson CSF for the delivery of 2048^2, 15 μm pixel, three-side buttable thinned CCDs. Negotiations for the procurement of similar devices are going on with EEV and Lincoln Lab. It is likely that in 1995 - 1996 some of these developments will be successful and the first mosaics with high performance devices will be assembled.

The results on the intrapixel variations of the QE presented by Jorden and Oates (1995) deserve also special attention. They have to be taken into account in evaluating the photometric accuracy and the positioning accuracy to be extracted from a given CCD-camera combination.

2.2 Read-Out-Noise

Values of 2-5 e^- have been achieved at different observatories using chips from SITe, EEV and Thomson. The use of the so-called skipper on-chip amplifiers introduced a few years ago should permit a further reduction of the read-out-noise by multiple readout of the pixels and subsequent averaging of the values. To my knowledge, there has not been any astronomical use of these devices (mounted on a number of Loral CCDs) yet. The sampling of the pixels required to achieve low values of the read-out-noise is relatively long. This leads to overall read-out times of largest format CCDs of the order of three to four minutes. At present this time can be reduced only by the use of multiple outputs read-out, with the disadvantage of different calibration parameters for the different sections of a device and sometimes crosstalk between the different channels. High speed, low-noise amplifiers are now becoming available as reported by Luppino et al. (1995) in his talk. They are likely to become the preferred solution to the read-out speed problem in the future.

2.3 CCD Controllers.

The introduction of 2048^2 CCDs in the standard operation of most major observatories and the prospect of even larger mosaics of CCDs has driven the development of many new controllers based on the use of transputer modules and DSP. At this meeting we had the opportunity to hear directly on the status of different projects (ARCON from CTIO, SDSU from San Diego, ACE from ESO and the controller for the Italian Galileo telescope) and to witness a lively discussion on the relative merits of transputers and DSP. Equally interesting developments for the control of infrared detectors were reported by Finger et al. (1995) (ESO system IRACE) and Glass et al. (1995) (The Rutherford-SAAO controller). As a user, my impression is that there is no unique technical solution to the problem of building a fast, flexible CCD controller and the present technology does provide all the necessary tools to do the job. At the end the relative success of one system with respect to the other will depend more on factors like friendly user interface, reliability and simplicity of operation.

3. HOT TOPICS FOR FUTURE DISCUSSION

The symposium has provided an exciting, updated view of the current development in the field of array detector applications. Optical and infrared arrays play however such a central role in so many fields of modern astronomy that it is impossible to cover all applications in a single meeting. I give below my personal list of topics which, although of relevance, have not been discussed extensively at this meeting and should be kept in mind for future gatherings.

Astrometry was discussed in poster papers only. With the introduction of large size CCD detectors and mosaics of CCDs we can expect that CCD-based astrometry will become of increasing relevance. It would be of particular interest to discuss the requirements set by astrometric programs on CCD cameras and on the specific properties of the detectors.

At large telescopes the combination of better and larger detectors and improved image quality has opened the way to the deepest surveys at optical and infrared wavelengths ever done in astronomy. Special techniques are used to collect and combine several images and to reach the faintest magnitudes. A discussion of the results obtained so far and on the sources of errors is needed to identify the parameters of the detectors to be improved and the best technique for make further progress in this field. With single optical detectors now approaching the 4096^2 format and infrared detectors at the 1024^2 size, one of the more challenging problem in astronomical instrumentation is that of data transmission, preprocessing and archiving. The constraints are particularly severe in the infrared where the detectors have usually to be read at high frequency and through multiple outputs to avoid pixel saturation. The talks of Blecha (1995) and that of Cook (1995) on the CCD mosaic used for the Macho project have given some hints on these problems but the subject deserves much more attention in the future.

There was no talk dedicated to photon counting devices as detectors for the blue-visual spectral region. It is true that the applications where the use of CCDs is advantageous have increased because of their high QE and reduced read-out-noise, but photon-counting detectors are still the only detectors to be used when high time resolution is required, such as very fast photometry and speckle imaging. This type of observation is the key to many major astrophysical problems, so photon-counting devices are not to be forgotten, at least until they can be efficiently replaced by ultra-fast read-out CCDs.

REFERENCES

All the references are to IAU Symposium No. 167, New Developments in Array Technology and Applications, A. G. D. Philip, K. A. Janes and A. R. Upgren, eds., Kluwer Academic Pub., Dordrecht.

Blecha, A. 1995 IAU 167, p. 57
Bonanno, G. 1995 IAU 167, p. 39
Cook, K. H. 1995 IAU 167, p. 285
D'Odorico, S. 1995 IAU 167, p. 9
Fazio, G. G. 1995 IAU 167, p. 93
Finger, G., Nicolini, G., Biereichel, Meyer, M and Moorwood, A. F. M. 1995 IAU 167, p. 81
Gezari, D. Y. 1995 IAU 167, p. 97

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Gilmore, K., Rank, D. and Temi, P. IAU 167, p. 79
Glass, I. S., Sekiguchi, K. and Nakada, Y. 1995 IAU 167, p. 109
Iwert, O. 1955 IAU 167, p. 67
Jorden, P. R. and Oates, A. P. 1995 IAU 167, p, 27
Luppino, G. A., Mezger M. R. and S. Miyazaki 1995 IAU 167, p. 297
McLean, I. 1995 IAU 167, p. 69
Moseley, H. 1955 IAU 167, p. 95
Stover, R. J., Brown, W. E., Gilmore, D. K. and Wei, M. 1995 IAU 167, p. 19
Ueno, M., Tsumuraya, F. and Chikada, Y. 1995 IAU 167, p. 117