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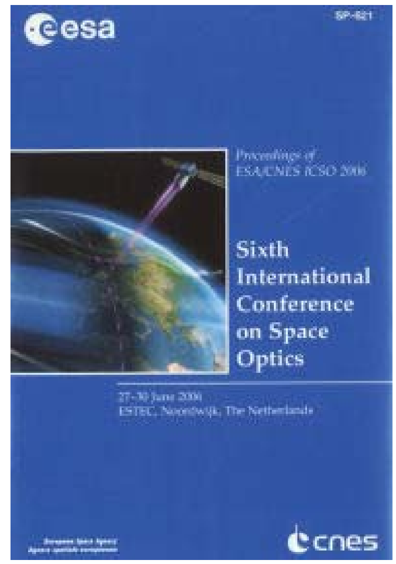

Micro optical sensor systems for sunsensing applications

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MICRO OPTICAL SENSOR SYSTEMS FOR SUNSENSING APPLICATIONS

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ABSTRACT

Optimum application of micro system technologies allows building small sensor systems that will alter procurement strategies for spacecraft manufacturers. One example is the decreased size and cost for state of the art sunsensors. Integrated sensor systems are being designed which, through use of microsystem technology, are an order of magnitude smaller than most current sunsensors and which hold due to the large reproducibility through batch manufacturing the promise of drastic price reduction. If the Commercial Of The Shelf (COTS) approach is adopted by satellite manufacturers, this will drastically decrease mass and cost budgets associated with sunsensing applications.

1. SUNSENSOR DEVELOPMENTS

TNO Science and Industry (formerly known as TNO TPD) is well known as manufacturer of high reliability sunsensors, such asthe sun acquisition sensor that is used (and will be used) on a multitude of satellites and the fine sunsensor for the Gallileosat constellation.

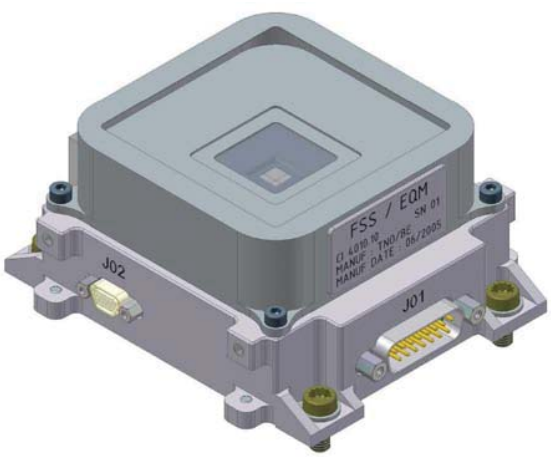

Fig. 1. Gallileosat Fine SunSensor (FSS)

All of these sensors are characterized by the high reliability obtained through years of experience and elaborated testing.

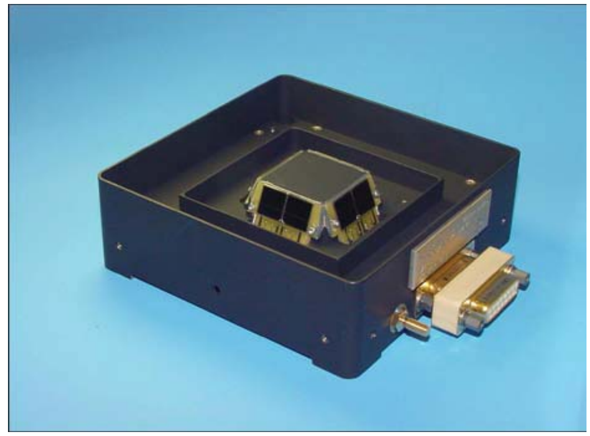

Fig. 2. Sun Acquisition Sensor (SAS)

More recently (in the frame of the Dutch microsatellite program MISAT) TNO has started work on miniaturized versions of sunsensors that hold the promise of leading to much smaller sensors that can also be used on board of satellites that are too small to sensibly carry the conventional sunsensors.

Although significant development effort is still needed to lead to a situation in which these sensors have the same proven reliability as the conventional ones, the main advantage of these sensors is the fact that they will lend themselves for batch production using mass manufacturing technologies like wafer to wafer bonding etc.
Using such technologies will allow to manufacture comparatively large batches of sensors that have a very high degree of similarity.
This in turn will allow for a batch testing approach.

Given the fact that a large part of the costs associated with the more conventional sensors is related to the labour intensive assembly and testing, the before mentioned technologies will allow for a significant cost saving without sacrificing the quality of the end product.

Currently two products are under development that are likely to be mass producible.

One product concerns the micro digital sunsensor for use on the Dutch MicroNed satellite project MISAT.

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The sensor consists of a dedicated Active Pixel Sensor (APS) that includes both an Analog to Digital converter and the required digital signal processing for centroïd calculation of the sunspot, incident on the the APS sensor through a membrame pinhole in front of the detector device
The membrane is mechanically bonded to the APS directly leading to a very compact, rigid and low power sunsensor.

The low power demand of the dedicated APS enables the use of a system-integrated solarcell power supply.
Incorporation of a dedicated wireless datalink to transfer the sensor data to the S/C subsystems completes a fully autonomous sunsensor (fig. 3.).

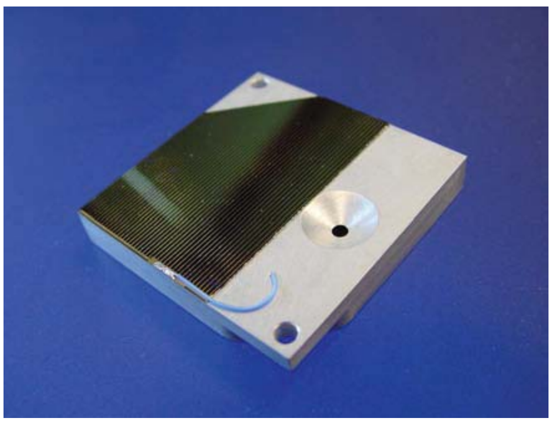


Fig. 3. Micro digital sunsensor (μDSS)

In the schematic cross section in fig. 4 it can be seen that the number of components used is minimised and that the membrane is directly bonded to the chip.

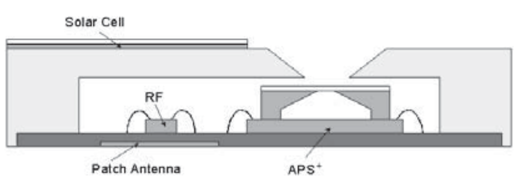


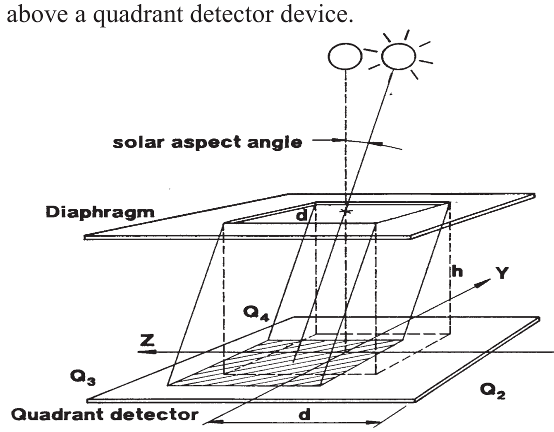
Fig. 4. μDSS cross section.(not to scale)

The μDSS is expected to have an accuracy in the order of 0.03 degrees of arc in its FOV of 128 x 128 degrees of arc. By virtue of its pixel sensor this accuracy is maintained even if planet (earth) albedo would be in its FOV.

Handicaps for immediate implementation of the micro-DSS are the facts that the development of the dedicated APS will still require some time and that there are no satellite bus structures available yet that use a wireless data transfer infrastructure.

To circumvent these "problems" the immersed sunsensor is currently under development.

The patented immersed sunsensor uses the same principle as the Gallileosat fine sunsensor in the sense that a membrame is suspended at a known distance above a quadrant detector device.



$$S_y(\alpha) = \frac{tg\alpha}{tg\alpha_{max}} = \frac{Q_1+Q_2-Q_3-Q_4}{\Sigma Q}$$

$$S_z(\beta) = \frac{tg\beta}{tg\beta_{max}} = \frac{Q_1+Q_4-Q_2-Q_3}{\Sigma Q}$$

Fig. 5. Operating principle FSS

The main difference with existing conventional sunsensors is the fact that the spacer between the diaphragm and the quadrant sensor in this case is a glass plate.The aperture membrame is deposited on one side of the glass. The quadrant sensor is deposited on the other glass face and becomes backside illuminated.

The glass plate can be Cerium oxide doped for radiation hardness and polished to a high accuracy without much effort resulting in a comparatively inexpensive sensing core.

Both the quadrant sensor and the aperture mask (with a size in the order of 1 cm² are deposited in a vacuum depositing process that used a 6 inch glass substrate, thus allowing to make more than a hundred sensors at the same time with a positioning repeatability in the range of micrometers.
Therefore it is expected that the main sources of error (caused by mask alignment) will be very similar for all of the produced sensors.
This will allow the production of many sensors simultaneously and to test only a limited number of them to provide batch qualification.

The expected accuracy for the sensor is better then 1 degree of arc for a field of view of 128 x 128 degrees of arc.

The size of the sensor is such that packaging becomes a real issue.
For the immersed sunsensor the same philosophy as for the Gallileo FSS is adapted in the sense that the preamplifiers and the multiplexer will be included in the package, to reduce the number of datalines that are required and to reduceEMC sensitivity.
The package will be fitted with a micro-D connector, which is the smallest commonly available space qualified connector.

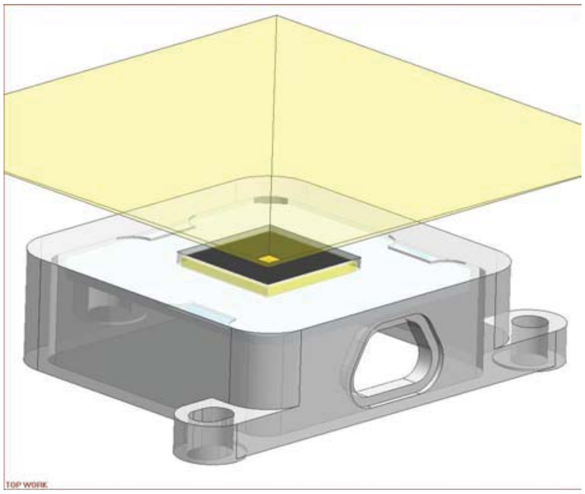


Fig. 6. Packaged immersed sunsensor preliminary design (yellow cone represents the unobstructed FOV)

The chosen approach is one of the many possible applications, while due to the extreme rigidity of the sensor other applications like measuring the orientation of solar arrays can be thought of which would most probably require a different packaging and connection philosophy.

In any event the sensors will be so small and rigid that a generic qualification against extreme levels of vibration and other environmental strains can be performed allowing to use the sensor for multiple missions.
This again leads to a situation where sensors can be delivered at minimal additional costs once the generic qualification can be accepted.

Overall this might lead to a different redundancy and procurement strategy for satellite builders.
Lower mass and prices mean that there will be a high preference to use standard microsensors in stead of customised once.
The lower procurement cost even allows to add extra redundancy thus increasing reliability of the system.

Once wireless datalinks are adopted for space applications, sunsensors could start to look quite different from what we are used to nowadays.

In case the solarcell and patch antenna are integrated together with a small diaphragm, a highly compact sunsensor can be devised for which the main problem will be the mounting and alignment on the spacecraft.

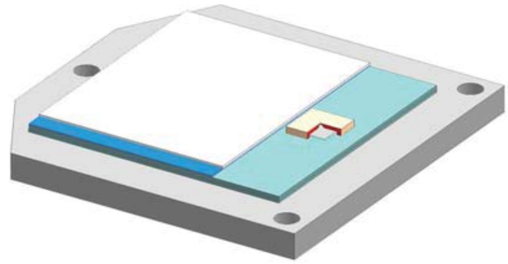


Fig. 7. Ultimate sunsensor.

Although all needed technologies are available nowadays, and a real implementation is only limited by the amount of money available, it will take at least a number of years before sunsensors in this form will appear (if they will appear at all)
This is because extreme integration also requires extreme investments which may not be worth wile unless other applications are found that justify the level of investment required.

For the moment the size and mass gains that can be realised with the currently on-going developments is such that they are deemed worth wile because they open up the market of micro and nanosatellites and provide a significant mass, size and cost gain for all other systems.

CONCLUSION

Recent developments in the field of miniaturized sunsensors might well change the procurement strategy for satellite manufacturers to a true COTS approach, thus reshaping the sunsensor market.