Dawn Framing Camera
A Telescope En Route To The Asteroid Belt

H. Sierks K.-M. Aye I. Büttner R. Enge W. Goetz P. Gutierrez-Marques
H. Hartwig I. Hejja H.U. Keller W. Kühne T. Maue A. Nathues
M. Richards R. Schäfer S. Schröder M. Sperling I. Szemerey

S. Mottola T. Behnke U. Carsenti R. Jaumann M. Tschentscher

B. Fiethe F. Bubenhagen H. Michalik K.-U. Reiche

Abstract

The Framing Camera (FC) is a German contribution to the Dawn mission in flight to the asteroid belt. We describe the instrument implementation and show some results of the early operational phases

Science Objectives

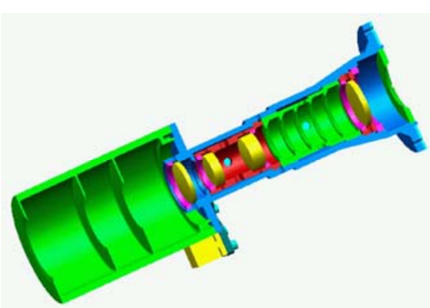
Dawn is a JPL/NASA Discovery mission that will orbit the asteroids 4 Vesta and 1 Ceres to compare their evolutionary path and characterize the conditions in the early solar system.
To perform its mission, the spacecraft carries a Framing Camera, a Visible and InfraRed spectrometer (VIR) and a Gamma Ray and Neutron Detector (GRAND)
The Framing Camera will contribute in the following aspects

- Volume of the asteroids
- Spin state
- Shape, topography
- Interior structure
- Physical surface properties
- Color variation and mineralogy
- Evolution (crater records)
- Environment (dust and satellites)

The Framing Camera will also be involved in optical navigation, orbit determination and mission safety.
The profile of the mission, that was launched in September 2007 and will arrive at Vesta in late 2011 and at Ceres in late 2015, imposes special restrictions to the use of moving parts.

Architecture

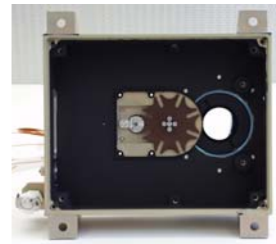
The Framing Camera is a refractive telescope equipped with a frame transfer CCD sensor. The camera is structurally divided into camera head and electronics box. The cooling necessary for an adequate performance of the sensor is provided by two passive radiators that dissipate the heat into deep space.
The camera head contains the sensor, the readout electronics, the interference filters, the optics and the radiators. The CCD is thermally isolated from the electronic box and its temperature is independently controlled by heater mats.
The electronic box contains the data processing unit, the power converter unit and the mechanism controller, and is thermally attached to the spacecraft, which dissipates the heat through its own radiators.
Both boxes are mechanically attached by isolating feet and electrically connected through a harness that minimizes the thermal connection.



The telescope

In order to fulfill the mission requirements within the allocated mass budget, the telescope has a 150 mm telecentric anastigmatic design. This 4-lens construction provides an aperture of 20 mm and a field of view of 5.5° x 5.5°. During its lifetime, the telescope is expected to experience a wide range of thermal conditions. Thermal expansion is compensated for by using different materials in the lens barrel that will keep the optics in focus throughout the expected range of temperatures.
Chromatic aberration of the system is minimized by using filters of different optical thickness of the filters that are located between the optics and sensor.
The requirement to minimize the amount of stray light is fulfilled by a front external baffle and a number of internal shades. Additionally, the front baffle is equipped with a front door that protects the whole system against contamination and the harmful effects of the Sun during the non-operational phases.

The filter wheel



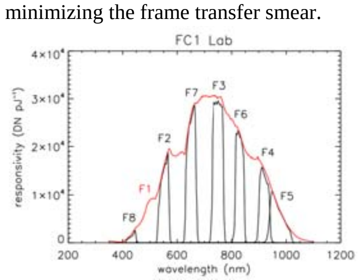
The multi-spectral capability of the camera is provided by a filter wheel in the optical path, which contains one broad- and seven narrow-band filters.
Rotation of the wheel is controlled by a Geneva drive that achieves the step-wise movement with only two moving parts and locks the wheel into the correct position.

The sensor

The selection of the sensor was driven by several factors:

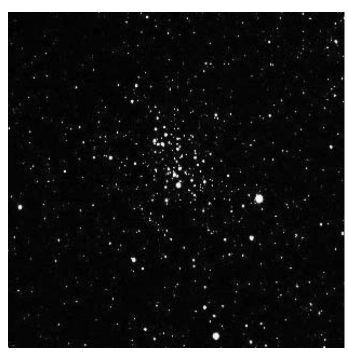
- The absence of an atmosphere around the asteroids produces big contrasts between the well lit areas and those in shadow, imposing the requirement of a very wide dynamic range
- The need to observe both very bright asteroids and very dim stars for navigation requires the possibility to expose for periods in the order of milliseconds to hundreds of seconds
- To minimize the mechanical complexity, the CCD requires an electronic shutter
- Cost constraints called for a commercial CCD rather than a tailored development

The selected sensor is a Thomson TH 7888A, a 1024 x 1024 pixel frame-transfer CCD. This is a commercial device equipped with an electronic shutter. Its high performance enables a 1.3 ms frame transfer, minimizing the frame transfer smear.
The 14 µm pixel pitch, combined with the optical system provides an angular resolution of 96 µrad that will translate in a resolution of 17 m/pixel at Vesta and 66 m/pixel at Ceres.
The combined sensitivity of the system varies between 2 and 30 DN / nJ depending on the filter.



Data processing unit

The data processing unit is a fully-featured onboard computer. It is based on a radiation-resistant Xilinx implementing a Leon core and features 8 Gib triple redundant mass memory.
The flight software is the combination of an off-the-shelf real-time operating system, a middleware layer to address the specifics of the instrument subsystems and user-level software that can be easily modified to serve the needs of scientists.



Results

During the checkout and early cruise, FC1 and FC2 have acquired respectively 728 and 1172 images with impressive results. A sensitivity analysis shows that magnitude 16 stars can be identified in 10 min deep exposures.
The image on the left shows an amazing view of NGC 3532 star cluster (The Wishing Well).

The image on the right, taken over Terra Tempe during the Mars flyby in February 2009, showed an excellent resolution in spite of the poor illumination and the hazy atmospheric conditions, and proved that the Framing Camera will be an excellent instrument for topography reconstruction at the asteroid belt.