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XRF Experiment for Elementary Surface Analysis

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Abstract

The proposed X-Ray Fluorescence Instrument Package (XRF-X and XRF-E) is being designed to quantitatively measure the composition and map the distribution of rock-surface materials in order to support the target area selection process for exploration, sampling, and mining. While energy-dispersive X-Ray fluorescence (EDX) makes use of Solar X-Rays for excitation to probe materials over arbitrary distances (by XRF-X), electron-beam excitation can be used for proximity measurements (by XRF-E) over short-distance of up to about 10 - 20 m.

This design is targeted at observing and analyzing surface compositions from orbital platforms and it is in particular applicable to all atmosphereless solid-surface bodies. While the instrument design for observing objects in the outer solar system is challenging due to low count rates, the Moon and objects of the asteroid belt usually receive solar X-ray radiation that allows to integrate a statistically reliable data basis.

Asteroids are attractive targets and have been visited using X-ray fluorescence instruments by orbiting spacecraft in the past (Itokawa, Eros). They are well-accessible objects for determining elemental compositions and assessing potential mineral resources.

1. Instrument Details

The XRF-X experiment package consists of three subsystems: (1) the main instrument targeting the asteroid's surface, (2) a zenith-pointing solar monitor which incorporates calibration targets for accounting the solar X-Rays and particles, and (3) a platform for rotation and tilting, to point the main instrument's collimator to each desired direction.

1.1 XRF-X for remote Measurements

By monitoring incident Solar X-ray (and possible particle flux) through synchronous measurement of a calibration target in XRF-X, measurements can be obtained even over long distances, e.g. on a fly-by maneuver. A scalable and modular design allows for instrument adaptions to, e.g., desired resolution and sun emission intensities and to weight and power-consumption constraints. Instrument calibration details are treated in an accompanying abstract by Dreißigacker et al.

1.2 XRF-E for proximity Measurements

The use of electron-beam excitation in XRF-E, comparable to a macroscopic version of X-Ray microanalysis in scanning electron microscopes, is a sensitive tool for high resolution element mapping of objects over distances of up to 20 meters, depending on electron-beam current and detector area. The measurements are independent of solar influence, in this case a solar monitor is not necessary.

2. Measurement Scope

The XRF-X and XRF-E instruments both provide direct measurements that are being acquired independently from other measurements. They will allow to map concentrations of the main mineral- (and therefore rock-) forming elements of surface materials, in particular Na, Mg, Al, Si, K, Ca, Ti, Mn, Fe (atomic numbers 8 - 32). In the current laboratory setup both experiments are developed using large-area swept charge devices (SCD) to allow for high X-Ray returns.

The following features shall be implemented for both instruments (XRF-X and XRF-E):

• Scanning of the asteroid's surface in the X-ray spectral range of 500 eV to 10 keV (2.5 - 0.12 nm) with a spectral resolution of approximately 160 eV at 6 keV.

• Single photon counting and on-board histograming of X-ray spectra.

• Providing data for map generation of elemental abundance.

3. Figures

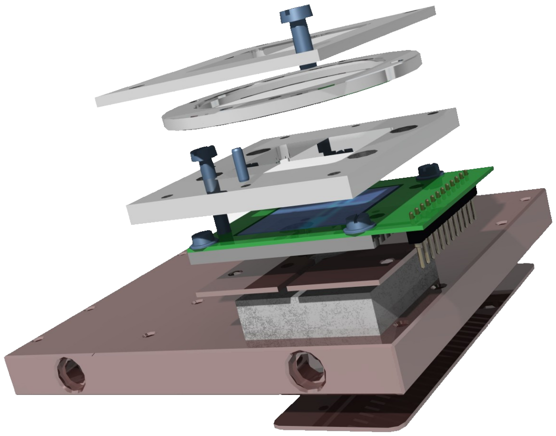

Figure 1: Laboratory assembly of SCD with X-Ray filter and cooling

4. Summary and Outlook

The X-Ray Fluorescence Instrument Package (XRF-X and XRF-E) can map the distribution of asteroid surface materials to support the target area selection process. The method has proven successful by orbiting spacecraft in the past (Itokawa, Eros). Currently, our laboratory components for XRF-X have passed TRL 4 and 5; TRL 6 is expected on end of 2014.

Acknowledgements

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