The SERENA package, a single Instrument Front End on board the BepiColombo/MPO, will investigate the Mercury’s complex particle environment that surrounds the planet. Such an environment is composed by thermal and directional neutral atoms (exosphere) originating via surface-release and charge-exchange processes, and by ionized particles originated through photo-ionization and surface release processes. In order to fulfill such an investigation, in-situ analysis of the environmental elements is needed.

**SERENA**: Search for Exospheric Refilling and Emitted Natural Abundances

Neutral Particle Analyzers (NPA)  Ion Spectrometers(IS)  
**ELENA**: Emitted Low Energy Neutral Atoms  **PICAM**: Planetary Ion CAMera  
**STROFIO**: Exospheres Mass spectrometer  **MIPA**: Miniature Ion Precipitation Analyzer

**Main Scientific Objectives**
- Exosphere Chemical /elemental composition  
- Exo-ionosphere  
- Gas density profile as a function of altitude  
- Particle loss rate from Mercury environment  
- Surface emission rate and release processes  
- Plasma precipitation rate

**Other scientific objectives**
- Remote sensing of the surface composition  
- Magnetosphere structure and dynamics  
- Solar wind at Mercury’s heliocentric distance  
- ENA imaging applications for comparative solar-planetary relationship studies

**Scientific objectives of each unit**

**NPA**: ELENA investigates the Hermean escaping neutral gas (strongly linked to its surface), and the processes responsible of such a population;  
**STROFIO** investigates the exospheric gas composition.  
**IS**: PICAM investigates the extension, composition, and velocity distribution of the exo-ionosphere, and the photo-ionization rate of neutrals.  
**MIPA** investigates the plasma precipitation toward the surface and ions energized and transported throughout the environment of Mercury;
**START section: shutter system**

The shuttering element of the ELENA detector consists in a couple of nanopatterned self standing silicon nitride membrane one facing the other and separated by a distance between 1 and 5 μm, in order to have the correct number of time of flight channels. One membrane is fixed while the second one is moved respect to the other by means of a piezoelectric actuator, at a frequency up to 50 kHz. The EQM ELENA shutter has been realized following several crucial step: mechanical realization, membranes production, mounting and alignment. The shutter has been tested with both Ion and Neutral beam at several frequencies.

**ELENA EQM shutter mounted in ELENA box with Piezo-board**

A new process realized during the etching procedures enhances the cleanness and the planarity of the silicon membrane, in the region surrounding the active zone, and allows to reach a closer distance between the gratings.

- Distance measurements are performed in the inner part of the gratings (blue circle)
- Distance corrections are realized by acting on the the screws in the outer part of the shutter (red circles)

**Shuttering Test results with Ion and ENA beam**

Shuttering is performed to test the device. Here we report the record of ELENA shuttering action static and dynamic, at 10, 42 and 52kHz. The tests have been performed under intense 400nm laser illumination to have a good transmission through the 200nm slits. ION and ENA beam test have been performed at INAF–IAPS facility and at University of Bern- MEFISTO facility, respectively.

**MCP detection efficiency for Low Energetic Neutral Atoms. Test performed at MEFISTO facility in Bern.**

MCP of the same characteristics of ELENA EQM-FM model has been tested with ENA beam of different species (Hydrogen, Helium and Oxygen) for non-coated standard MCP and coated MCP (coating CsI-MgO). The results (reported by Rispoli et al., 2012) allows to select the MCP type and to evaluate the ELENA capability to detect signal.
SERENA / STROFIO status update

Strofio Molecular Contamination Issues

- BepiColombo spacecraft outgassing will limit the capabilities of a mass spectrometer to measure small amounts of the exospheric gas
- Mercury’s exosphere has a total pressure of about $10^{-10}$ mbar at the surface, at most $10^{-11}$ mbar at 400 km altitude
- Spacecraft background data estimated from data of the Rosetta spacecraft

<table>
<thead>
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<th>Element/Molecule</th>
<th>Source</th>
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Forecast of Signal Around Mercury

- Highlighted in blue are the measured species
- Velocity filter rejection will reduce the background by a factor of 10-20 (still in calibration); here assumed the optimistic 20
- Red are species we will not be able to measure, yellow the ones with S/N small, green the one we will be able to measure (in {} estimated values from RTOF)
- An increase of the pressure by a factor of 10 would blind out almost all of the species

Note: we will not be able to measure $^{32}$S, as it has the same m/q as the much more abundant $^{16}$O₂, but we would be able to measure $^{34}$S, which has an isotopic abundance of 4%

The SERENA team, in order to prevent serious damages to the science return of STROFIO, requires that the MPO outgassing contamination level surrounding the satellite during in-orbit operations should never exceed $10^{-10}$ mbar total pressure, and $10^{-13}$ mbar partial pressure at any chemical component.
Two areas requiring modifications of the ion optics were identified:

- **Gate Electrodes**: Capacitance between + and – electrodes as well as between electrodes and ground shall be reduced.

  This was achieved by replacing metallic parts of the electrode fixations by Duratron.

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**QM TOF Measurements**

- **Beam**
  - Nitrogen molecular (N$_2^+$)
  - Energy 100eV
  - Flux 100cps

- **Starts** (gate opening)
- **Stops**
- **TOF Gas expected**

- **TOF ≈ 6µs**

Theoretical period of 10ms

Measured period: 9.9426ms (+/- 800ns)

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**QP Ion Optics Testing w/o Gate**

- Energy resolution in range predicted by model.

- Elevation angle response verified using simplified detector.

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**Pixel Maps with Monodirectional Ion Beam**

- **500 eV Beam Energy**
- **Elevation angle**

  - 40
  - 50
  - 60
  - 70
  - 80
MIPA is a low-resource robust budget sensor optimized for monitoring of the ion precipitation flux, and is the mature 4th generation of this sensor family. It’s predecessors are YPP1 and 2, SWIM, PRIMA and DIM - all variants of the same technology. MIPA is designed for a 2s FoV and to sustain the very high demanding thermal environment which is the consequence of a Mercury orbit. The deflection system located outside the high temperature MLI is designed, and proven to withstand an operational temperature of up to 400 °C, but yet thermally decoupled from the sensor unit and space craft by a titanium decoupling tube of only 40 mm in length.

The final MIPA Flight Model (FM) design is based on all results and experiences from it’s predecessor sensors and models. It is proven to withstand the thermal and mechanical load it will experience from launch - until end of life in Mercury orbit. It’s functionality is heavily tested and proven from previous flight experiences and from the calibration of the MIPA Qualification Model (QM).

MIPA STM

In order to protect the MIPA sensor and electronics as well as the spacecraft, the selection of material and coating of the MIPA aperture is optimized for as low coating ratio as possible. What the aperture absorbs from sun and albedo illumination, it must be able to irradiate, without heating the MIPA sensor and spacecraft - and at low temperature as possible. A 10x solar constant test conducted at the University of Bern proves the MIPA apertures capability to do just that. The test covered steady state verifications as well as an in-orbit cycling (illumination and eclipses). The key conclusions from the tests are:

1. The thermal decoupling of the tube is nominal. MIPA aperture exposure until steady state gave a temperature increase of only 13 °C at cold sensor-side of the tube, while the warm side increased by 240 °C.
2. The coating was stable throughout the test, and fulfills the requirements. A comparison between all test results show a very similar behavior in both absolute steady state temperatures as well as in time constants.
3. Cycling test proves thermal stability. Evolution of temperature over cycles repeats, and does not increase.
4. Post-test inspection: No effects of thermal stress identified.

MIPA status

- MIPA QM/FS pre-calibration completed
- HT-MLI contamination test and evaluation completed
- ASD contamination protection cover impact assessment and mechanical analysis completed.

Current on-going

- FM aperture coating
- FM board population
- FM integration
- SCU#2 support. MIPA DDM - SCU#2 S/W support
- MIPA QM delivery for SERENA EMC test
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