The Large Imaging Spectrometer for Solar Accelerated Nuclei (LISSAN): A Next-Generation Solar gamma-ray Spectroscopic Imaging Instrument Concept

Frontier Detectors for Frontier Physics
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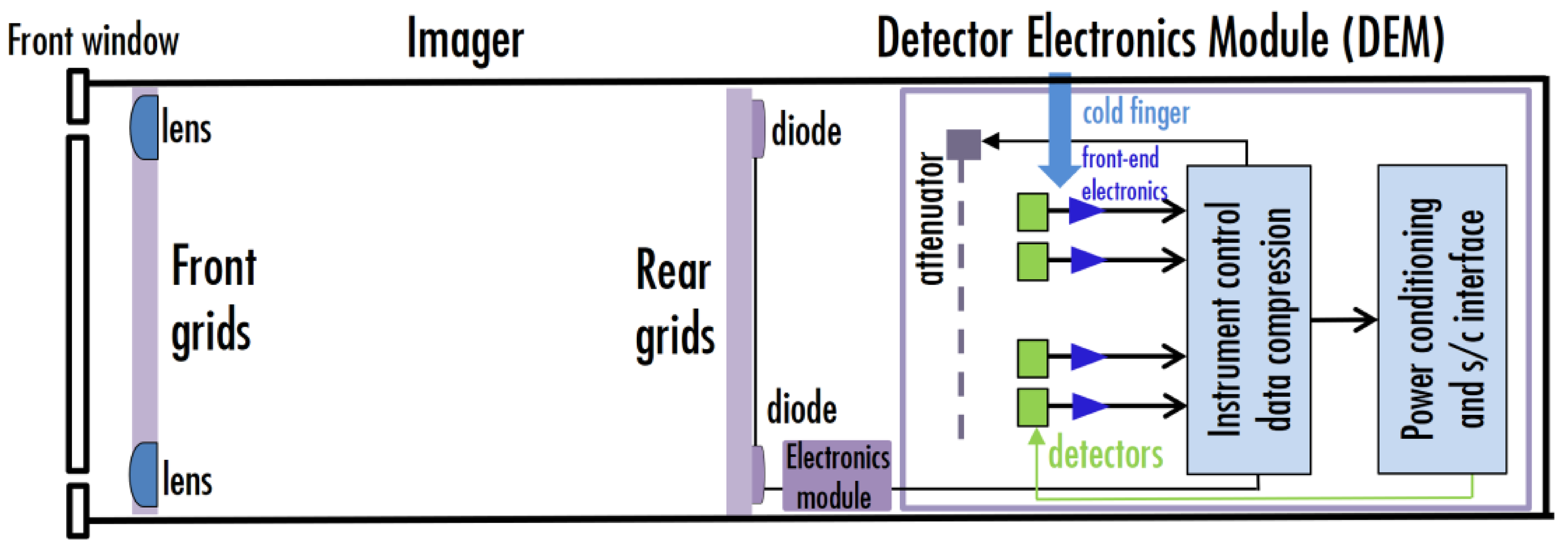
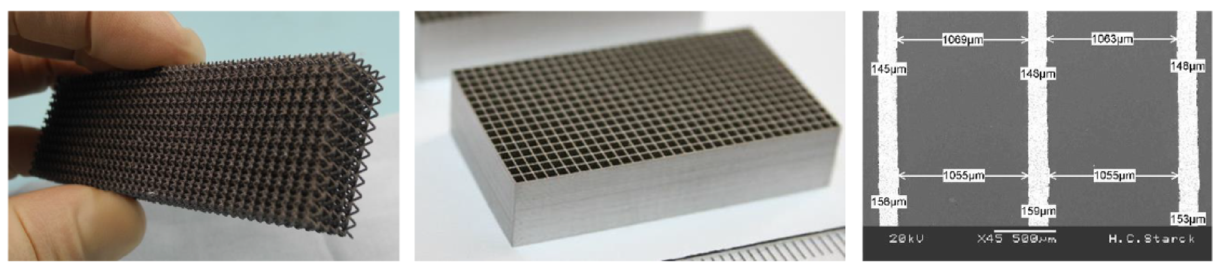
We present the large imaging spectrometer for solar accelerated nuclei (LISSAN), a new solar dedicated satellite instrument concept. LISSAN relies on an indirect Fourier imaging technique valid over an energy range of 40 keV up to 100 MeV. Spatial information is encoded into 15 moiré patterns by 15 pairs of slightly offset grids (bigrids) separated by a fixed distance enabling a predicted spatial resolution of 10″. The time, location, and energy of each incoming photon is recorded via a pixelated gadolinium aluminum gallium garnet (GAGG) crystal scintillator detector placed in alignment with each bigrid, therefore providing simultaneous imaging and spectroscopy from the same imaging system. X-ray and gamma-ray emission are key diagnostics of electron and ion acceleration, respectively. However, despite being a fundamental process that occurs throughout the Universe, particularly in the solar atmosphere, only one resolved gamma-ray image of ion acceleration in a solar flare has ever been achieved. LISSAN will shed new light on this process by providing spectral resolution better than 1.5% FWHM at 6.1 MeV, an imaging effective area at 2.2 MeV of 100 cm^2 (more than 25 times greater than past missions such as RHESSI) and a 10 second cadence. Thanks to these significant advances over the previous satellite-based solar detectors, LISSAN will provide reliable imaging and the spectral characterization of both electron and ion acceleration in solar eruptive events simultaneously for the first time, enabling to it to answer several important open questions regarding solar particle acceleration and the initiation of space weather events.

Instrument Concept



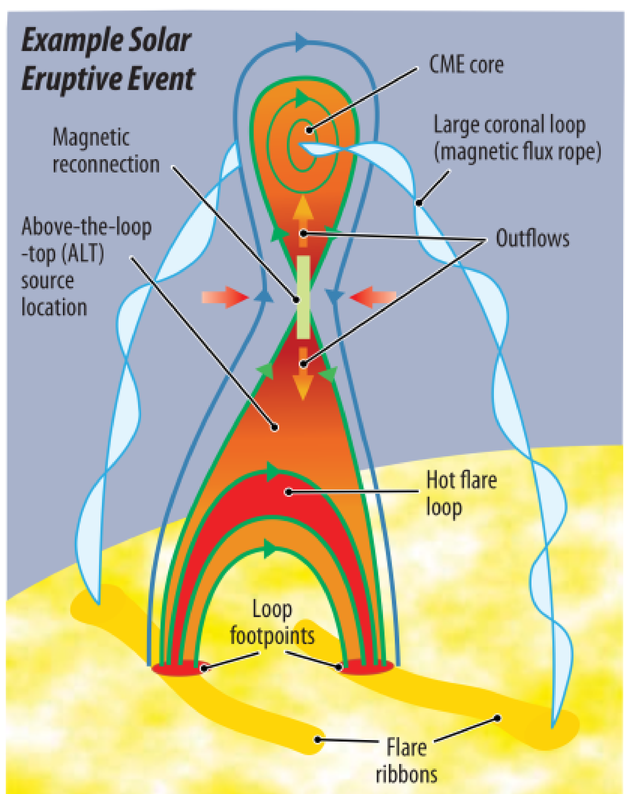
- Indirect Fourier imaging technique which is valid across its entire spectral range
- Spatial information is encoded into 15 moire patterns by 15 pairs of slightly offset grids (bigrids) separated by a fixed distance
- Each bigrid is aligned with a pixelated GAGG crystal scintillator detector which records the time, location, and energy of each incoming photon

The Grids



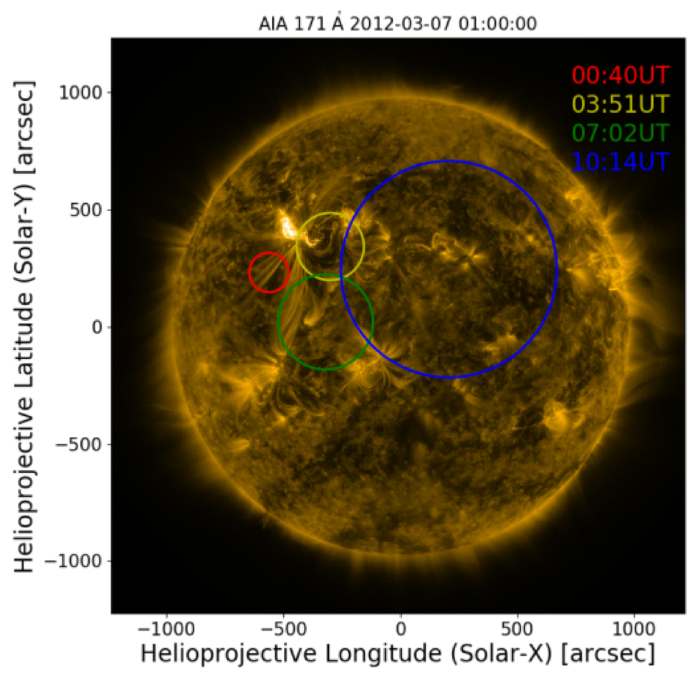
- Choice of grids based on physics-driven tradeoff among angular resolution, FOV and maximum energy
- FOV constrained by the ratio of slit width/grid thickness, angular resolution (0.5 slit pitch / separation), maximum energy determined by the grid thickness
- The pitches range from 230 μm to 3720 μm, thickness is 3 cm, separation between front and back grids is 3 m
- Manufacturing grids with such an extreme thickness-to-pitch aspect ratio is challenging
- Feasable alternative manufacturing methods in 3D printing:
  - Laser powder bed fusion or three-dimensional screen printing

Unresolved Questions Regarding Ion Acceleration in Solar Eruptive Events



Do ion and electron acceleration share a close physical relationship?

- Event integrated fluences of two populations found to correlate over 3 orders of magnitude
- But there are cases where spatially integrated time evolution of the two emissions dominate at different times
- Differences in relative locations between the two emissions suggest potentially different acceleration paths



How are ions accelerated on hour-long scales?

- More than half γ-ray flares exhibit hour-long emission
  - Flare signatures absent at other wavelengths
- Movement of the γ-ray emission over hour time scales suggest an extended acceleration source
- Need improved angular resolution observations to identify the source

LISSAN Instrument Requirements

LISSAN Parameter	Performance Requirement
Energy range	40 keV - 80 MeV
Imaging effective area (2.2 MeV)	75 cm^2
Spectral effective area (2.2 MeV)	400 cm^2
Sensitivity (2.2 MeV)	50 photons/cm^2
Sensitivity (6.1 MeV)	5 photons/cm^2
Imaging time resolution	10 s
Angular resolution	<10″
Field of view	>10′ diameter
Energy resolution (6.1 MeV)	1.5% dE/E

- Imaging concept was pioneered and successfully employed by STIX on Solar Orbiter in the 4–150 keV energy range
- R&D as well simulations of the detector performance are ongoing

The Detectors

- Each detector is composed of a 4 × 4 array of gadolinium aluminium gallium garnet (GAGG) crystal pixels, which provide a total active area of 100 cm^2
- GAGG are fast (50–100 ns), bright (30–50 photons/keV), and non-hygroscopic
- They perform at moderate cooling temperatures compared to Germanium based detectors and have a high quantum efficiency in the γ-ray regime
- A single pixel is composed of a 2.5 × 2.5 cm^2 GAGG crystal with a thickness of 10 cm for good high-energy photon absorption