Shaking the WFI Optical Blocking Filters: Vibration of Foils Thinner than Paper

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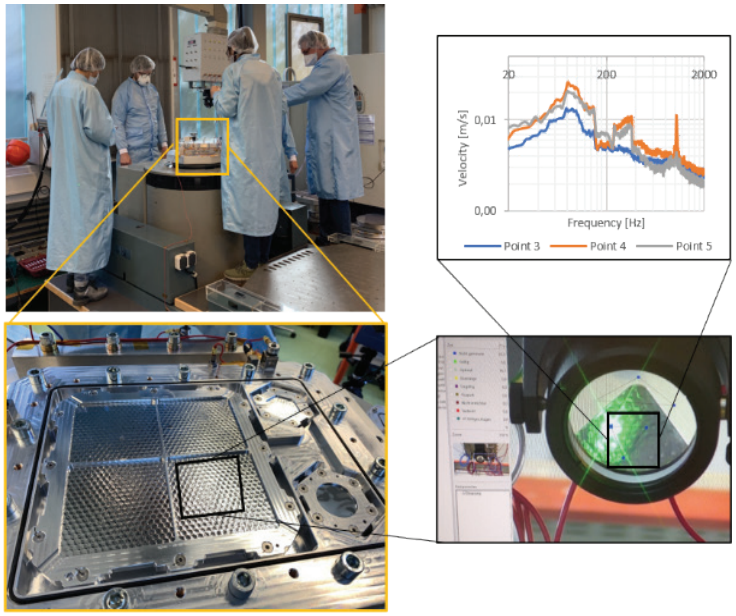

Vibration test on the shaker of MPE with a view of the full-size filter (left-hand side), and corresponding vibration measurement results on LDA filter (right-hand side). Credit: MPE.

Optical blocking filters (OBF), described in *#Athena*Nuggets 23 and developed at the University of Palermo and the University of Geneva, are mounted on a filter wheel placed in front of the WFI detectors. Their function is to block UV and visible light and allow the observation of very bright objects and exclusively study their X-ray components.

The challenge in the design of the filters is their dimension: they are made of extremely thin foils of thickness ranging from 150 to 200 nm. As a reference, the thinnest tissue paper is about 100 times thicker than one of these filters: if you breathe in their proximity you can see them vibrate! Naturally, the thinner the filter, providing the same functionality, the better, as the soft part of the X-ray spectrum will be less absorbed. The dimension of 160x160 mm of the Large Detector Array (LDA) in WFI makes its filter very sensitive to the mechanical loads occurring during rocket launch: *Athena* will in fact be subjected to extremely high loads originating from Ariane's engine at takeoff, mainly shock, dynamic vibration, and acoustic noise.

Launch loads occur simultaneously in real life, but are considered as separate load cases during testing because of their level of complexity: acoustic tests are carried out in facilities different from those used for vibration and shock due to the difficult control of interfering loads. Acoustic noise tests of the fully flight-representative filters were successfully carried out at AGH University in Krakow in July 2019, while the same filters were planned to be tested against vibration on a shaker at MPE in 2020.

Because of the COVID-19 pandemic, safe transport of the delicate filters from Palermo to Munich proved to be challenging and the presence of the colleagues from Palermo was not possible. Due to the optimal collaboration within the different working groups, INAF/UniPa anticipated the design of proper transport boxes, and the MPE team carried out the tests, while the Italian colleagues followed online, in a typical 2020 setting.

Dynamic response analysis of the complete WFI, including CBK's Filter Wheel design, was carried out to derive the load spectrum for the test. The filter test adapter was designed with the objective to represent the direct filter-surrounding volume as close as possible. The filters were tested in atmospheric pressure with a transparent protection cover, with slits enabling air ventilation as within the WFI. A laser vibrometer was used to determine the velocity of the filter foils during vibration, allowing additional measurements for accurate numerical verification and validation.

The successful completion of both tests for all filters, including the thinnest ones, signs an important milestone: the demonstration of their technology readiness, reaching the so-called TRL5. Further developments include the optimization of the WFI and the Filter Wheel in particular, with the use of the validated analytical models, with the constraint of keeping the dynamic loads on the filters within the tested envelopes.