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INSTRUMENT CALIBRATION REPORT

RESOLVE DETECTOR QUANTUM EFFICIENCY

RESOLVE-SCI-RPT-0057

REVISION (-)

XRISM-RESOLVE-CALDB-QUANTEFF-201

X-ray Imaging and Spectroscopy Mission (XRISM) Project

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Goddard Space Flight Center
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Space Administration

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RESOLVE DETECTOR QUANTUM EFFICIENCY
Signature/Approval Page

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Preface

This document is an XRISM Project signature-controlled document. Changes to this document require prior approval of the applicable Product Design Lead (PDL) or designee. Proposed changes shall be submitted in the Technical Data Management System (TDMS) via a Signature Control Request (SCoRe) along with supportive material justifying the proposed change. Changes to this document will be made by complete revision.

All of the requirements in this document assume the use of the word "shall" unless otherwise stated.

Questions or comments concerning this document should be addressed to:
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Change History Log

Revision	Effective Date	Description of Changes (Reference the SCoRe Approval Date)
-	09/03/2019	Released per RESOLVE-SCoRe-0297 Initial draft of CALDB file to set delivery format and pixel mapping. The QE curves use dummy values.

NOTE to editors: The document name will be XRISM-CAL-RPT-XXXX, where XXXX is assigned by the TDMS system. The document will be cross-referenced in TDMS to the filename in the format XRISM-XXX-CALDB-FILEDESC-NN where XXX is the instrument or component (e.g. RESOLVE), FILEDESC refers to a specific calibration report (e.g., rmfparams) and NN the corresponding number assigned to that report by the SDC. For example the calibration report addressing the Resolve LSF calibration may be assigned XRISM-RESOLVE-CALDB-RMFPARAMS-01, that addressing the Resolve gain calibration XRISM-RESOLVE-GAINPIX-CALDB-02, etc. (where the numbers are to be provided by the SDC).

These documents are updated as needed, e.g. when the relevant CALDB files, or the relevant calibration data analysis, is revised. The document version will be assigned by the TDMS system. The tracking tool should be used to record changes.

This document must include the CalDB file name, an explanation of how the data were collected and the analysis conducted and, if using standard Ftools, the software version number. All revisions are consolidated into the same document to maintain a full record of all changes.

Table of Contents

1 Introduction

1.1 Purpose

This document describes the measurements used and the calculations made to obtain the Quantum Efficiency (QE) for the Resolve detector array pixels. We define the QE as the x-ray stopping power of the detector pixels, which is determined by the x-ray absorber material (HgTe) and thickness. The filling fraction of the array is not addressed here; it is treated in detail using the Resolve teldef CALDB file [1], which contains the positions of the corners of each absorber, enabling calculation of the size and position of each absorber and the gaps in-between.

1.2 Scientific Impact

The QE is used in the Ancillary Response Function (ARF) calculation for spectral analysis and in the flat field for imaging analysis.

1.3 Background Information for QE Calculation

The QE of each microcalorimeter pixel describes the probability that a given x-ray will be stopped in the HgTe absorber. The QE of each absorber as a function of incident x-ray energy can be described using Equation 1:

$$QE(E) = 1 - \exp(-\mu_{HgTe}(E) * \rho * d) \qquad \textbf{Eq. (1)}$$

where $\mu_{HgTe}(E)$ is the mass absorption coefficient for HgTe, ρ is the density of the absorber, and d is the thickness of the absorber. The absorption coefficients for Hg and Te are known; assuming nominal stoichiometry of 1:1 we in turn know $\mu_{HgTe}(E)$ for the absorbers using the following equation:

$$\mu_{HgTe}(E) = (m_{Hg}\mu_{Hg}(E) + m_{Te}\mu_{Te}(E)) / (m_{Hg} + m_{Te}) \qquad \textbf{Eq. (2)}$$

where m_{Hg} and m_{Te} are atomic masses and $\mu_{Hg}(E)$ and $\mu_{Te}(E)$ are mass absorption coefficients from the literature (e.g., [2]). By measuring the area and the mass of the absorber we calculate the **"areal density" = Σ =** (mass of absorber / area of absorber). The areal density is equivalent to the quantity $\rho * d$. Re-writing Eq. 1 in terms of the areal density we find:

$$QE(E) = 1 - \exp(-\mu_{HgTe}(E)\ \Sigma) \qquad \textbf{Eq. (3)}$$

Assuming nominal HgTe density (ρ= 8.17 μg/ cm^3 [3]), the areal density also provides an estimate of the absorber thickness. Using Eq. 3 and neglecting uncertainty in the mass absorption coefficient, we derive the uncertainty on the QE:

$$\sigma_{QE(E)} = \mu_{HgTe}(E) \quad (1 - QE(E)) \quad \sigma_{\Sigma} \; . \qquad \textbf{Eq. (4)}$$

2 First Delivery – 20181220

CalDB Filename	Validity date	File(s) as delivered	Delivery date	Comment
xa_rsl_quanteff_20140101v002	20140101 00:00 UT	QE_PixelAssignments_Resolve_v0.1.txt QE_vs_Energy_Resolve_HgTe_v0.1.txt	20181220	Pixel assignments are final. QE vs E uses dummy values.

2.1 Data Description

For this first delivery, we do not use specific data regarding the quantum efficiency of the XRISM Resolve HgTe absorber tiles (e.g., thickness, areal density, etc.). That work is deferred to a later release of this file, and here we use dummy values to create the quantum efficiency curves.

We do provide an accurate mapping of what HgTe absorber tiles are attached to each sensor in the Resolve array. New HgTe tiles were procured from EPIR Technologies (http://epirtech.com) during the XRISM project and evaluated against spare HgTe tiles procured during the Astro-H SXS engineering model (EM) and flight model (FM) programs. Visual inspections and x-ray performance tests during the Resolve detector subsystem development program (~2018) showed significant differences among the batches [4], with excellent performance given by tiles from the batch used to populate the SXS FM array and from new HgTe material used when attached in a particular orientation (see below). Based on the availability of intact tiles from each lot and the associated performance results, the detector array was populated as summarized in Table 1.

Lot ID for XRISM CALDB	HgTe Batch ID from EPIR	Visual inspection	Use on Resolve Detector Array
Lot 1	MT811 (leftover from SXS FM array)	No discoloration on either face.	Used for 31 central pixels and calibration pixel. Placed numbered side down, same as for Astro-H SXS.
Lot 2	MCT830B1 (new material for Resolve)	Non-numbered faces are lightly discolored.	Used for 5 outer pixels. Placed numbered side up (discolored side toward sensor).

Table 1 Description of HgTe tiles used for Resolve detector array.

2.2 Data Analysis

No data analysis was performed for this first delivery. The analysis performed to generate the Astro-H SXS QE curve is detailed in Section 3.2 of Ref. [5]. A similar level of detail will be incorporated in future version of this document once QE curves specific to the Resolve detector array are delivered.

2.3 Results

Data files as delivered to SDC:
We provide two files.

The first file, QE_PixelAssignments_Resolve_v0.1.txt, provides a mapping of which QE curve is to be used for each pixel, based on the mapping of which HgTe tile (from lot 1 or lot 2) was attached to each sensor in the array. The file has two columns: pixel (0-35) and QEcurve (1 or 2). For easy reference, we copy the contents of this file here:

Pixel	QEcurve	Pixel	QEcurve
0	1	18	1
1	1	19	1
2	1	20	1
3	1	21	1
4	1	22	1
5	2	23	2
6	1	24	1
7	1	25	1
8	1	26	1
9	1	27	1
10	1	28	1
11	1	29	2
12	1	30	2
13	1	31	1
14	2	32	1
15	1	33	1
16	1	34	1
17	1	35	1

Table 2 Mapping of which QE curve is to be used for each pixel. These data are identical to those delivered in QE_PixelAssignments_Resolve_v0.1.txt.

The second file, QE_vs_Energy_Resolve_HgTe_v0.1.txt, has three columns: x-ray energy, QEcurve1, and QEcurve2. The energy range is 10 to 40000 eV with a step size of 0.25 eV. The absorber stopping power as a function of x-ray energy for the two lots of HgTe are provided in

QEcurve1 and QEcurve2. We use QE curves in the range of what is expected based on the likely range of absorber tile thicknesses; we set QEcurve1 equivalent to the final Astro-H SXS QE curve (HgTe thickness = 10.52 µm) [5] and QEcurve2 similar to what is expected from the nominal specified thickness (HgTe thickness = 8.5 µm). Neither curve includes detailed edge structure. Figure 1 shows the results. The curves were calculated using the nominal density and mass attenuation coefficients of HgTe as described in Section 1.3.

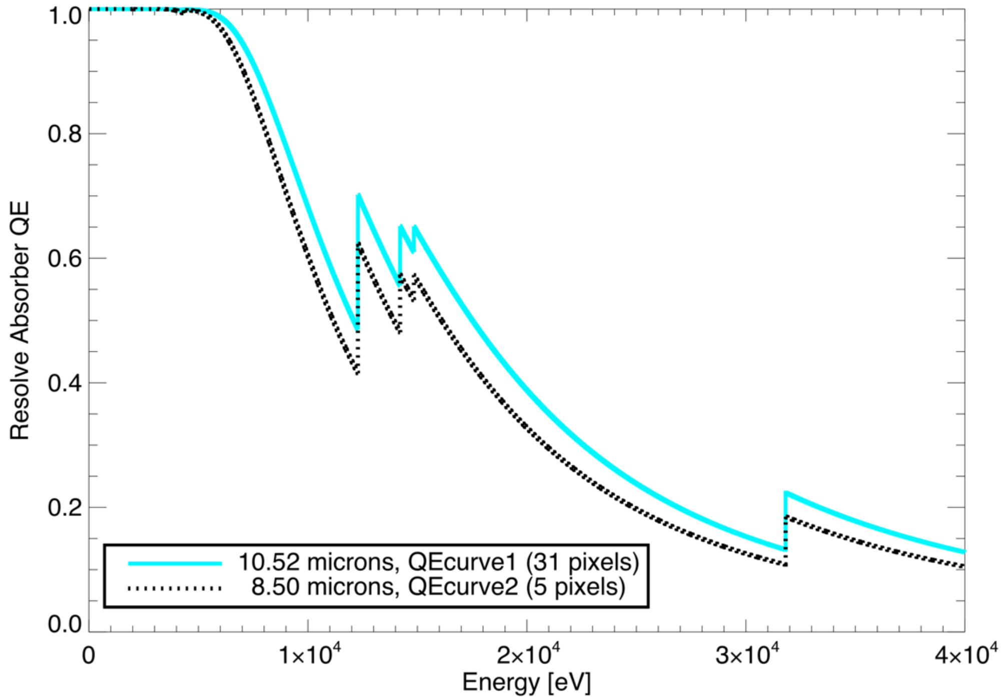

Figure 1 Absorber stopping power for two thicknesses of HgTe absorber tiles. Dummy thicknesses were used to calculate these curves, and they provide (realistic) examples only. The corresponding mapping of QE curve to pixel is provided in a separate file.

File in mission CALDB:
The Science Data Center (SDC) created xa_rsl_quanteff_20140101v002.fits, with a single energy column and 36 columns of QE curves (QE00 to QE35). The energy range remains 10 to 40000 eV with a step size of 0.25 eV. Each of the 36 QE curves corresponds to either QEcurve1 or QEcurve2 as specified in the instrument team input (QE_vs_Energy_Resolve_HgTe_v0.1.txt), with mapping determined by the pixel-to-absorber-lot list provided in QE_PixelAssignments_Resolve_v0.1.txt.

2.4 Final remarks

This is the first version of this CALDB file. The pixel-to-absorber-lot mapping is final, but the accompanying QE curves will be updated based on areal density and x-ray transmission measurements of HgTe absorber samples. The QE CALDB file format has changed from Astro-H, since for SXS all of the detector tiles came from a single lot and only a single QE curve was needed.

3 References

[1] M.E. Eckart, C.A. Kilbourne, et al. *Instrument Calibration Report, Resolve Absorber Corner Positions*, *XRISM-RESOLVE-CALDB-ABSCORNER-200*, in prep. (2019).

[2] B.L. Henke, E.M. Gullikson, and J.C. Davis. *X-ray interactions: photoabsorption, scattering, transmission, and reflection at E=50-30000 eV, Z=1-92*, Atomic Data and Nuclear Data Tables Vol. **54** (no.2), 181-342 (July 1993). http://henke.lbl.gov/optical_constants/asf.html

[3] D. L. Perry and S. L. Phillips, *Handbook of Inorganic Compounds*, CRC Press, Boca Raton (2000).

[4] C.A. Kilbourne, et al. *Evaluation of HgTe Absorber Samples Procured for Resolve, RESOLVE-DET-RPT-0025 v2*, (2019).”

[5] M.E. Eckart, et al. *Ground calibration of the Astro-H (Hitomi) Soft X-ray Spectrometer, JATIS*, **4(2),** 021406, (2018).