

3Pi Project

KU Leuven NBMSI Hardware Document

Technical Specifications

Version 1.1.0
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Contributors: Hendrik Hameeuw¹, Bruno Vandermeulen,² Michael B. Toth,³ William A. Christens-Barry,⁴
Lieve Watteeuw⁵

Camera	Lens	Filters	LED Panels	Transmitting Module
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INTRO: NARROW BAND MULTI-SPECTRAL IMAGING (NBMSI) SYSTEM

This document was created to provide an insight in and review on the technical infrastructure in use for the Narrow Band Multi-Spectral Imaging (NBMSI) system of the 3Pi Project (Book Heritage Lab, Faculty of Theology and Religious Studies, KU Leuven), operated in the Imaging Lab of the KU Leuven Libraries. At KU Leuven this narrow band multi-spectral imaging infrastructure has been obtained and is being operated within the framework of this 3Pi Project (*Diagnosis of Papyrus-Paper-Parchment manuscripts through advanced Imaging*, AKUL/17/001, FWO: I009918N, Mid-scale Research Infrastructure).⁶

This NBMSI system was created by R.B. Toth and Associates LLC, in association with Equipose Imaging LLC and Phase One A/S and their local partners; the acquisition software of the system is Spectral XV.

¹ Advanced Imaging, PhD., KU Leuven Libraries, Digitisation, Mgr. Ladeuzeplein 21 box 5593, 3000 Leuven, Belgium.

² Head of digitisation, KU Leuven Libraries, Mgr. Ladeuzeplein 21, 3000 Leuven, Belgium.

³ President and Chief Technology Officer, R.B. Toth and Associates LLC. 10606 Vale Road, Oakton, Virginia 22124, US.

⁴ Chief Scientist, PhD., Equipose Imaging, LLC. 4009 St. Johns Lane Ellicott City, MD 21042, US.

⁵ Prof. Dr., Book Heritage Lab – KU Leuven, Illuminare, Centre for the Study of Medieval Art, Charles de Bériotstraat 26, 3000 Leuven, Belgium, academic coordinator 3Pi Project.

⁶ The technical infrastructure acquired by the 3Pi Project is part of the Faculty of Theology and Religious Studies. Promotor-spokesman is prof. dr. Johan Leemans; coordinator is prof. dr. Lieve Watteeuw (Head Book Heritage Lab); implementation of the NBMSI system by Bruno Vandermeulen (Head Imaging Lab) & Hendrik Hameeuw (Advanced Imaging, Imaging Lab).

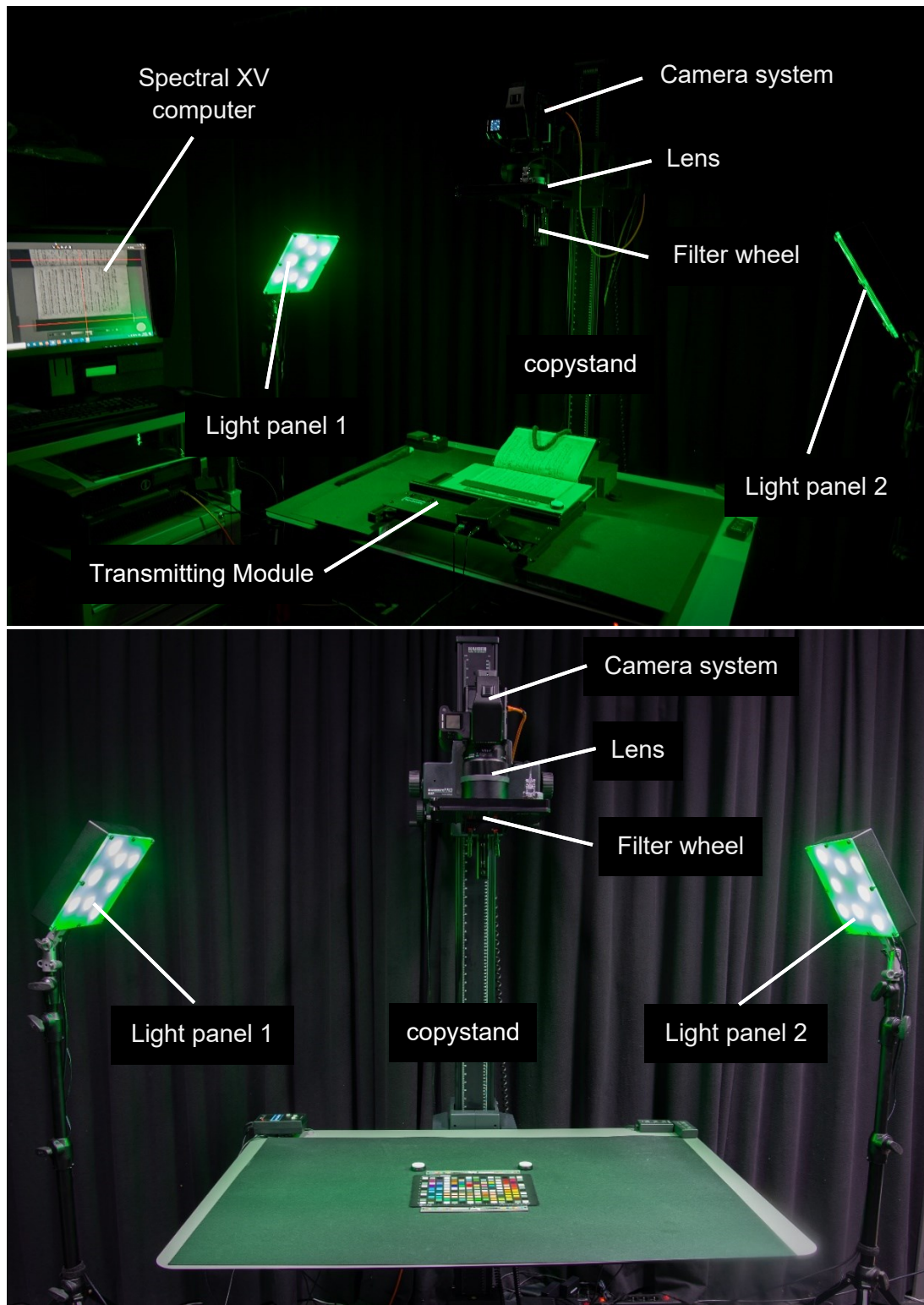


Fig. 1a & b – Spectral XV system: hardware

The NBMSI system at KU Leuven consists of:

- Phase one XF IQ4 150MP Achromatic Camera System (light sensor)
- Schneider Kreuznach 120mm LS f/4.0 Macro (lens)
- Filter wheel with band pass and long pass filters
- 2 Eureka light panels
- TX Transmitting Module
- Kaiser rePRO RSP (copystand)
- Spectral XV software

CAMERA

The NBMSI system at KU Leuven uses the [Phase One](#) XF IQ4 150MP Achromatic Camera System (serial JE000111), equipped with a Sony CMOS-BSI light sensor (datasheet via Sony manufacturer: product IMX411 or included in dataset of <https://doi.org/10.5281/zenodo.4548090>)¹¹ with 14204 x 10652 active pixels and measuring 53.4mm x 40mm; ISO sensitivity: 200-102400. The body and digital back are connected with the operating computer and is commanded by the Spectral XV software.



Fig. 2 – IQ4 150MP Achromatic digital back (from https://youtu.be/9k_AQmu5s1g)

¹¹ Always take in mind to consult the newer versions of this same document, they will have another DOI. The DOI for all versions of this document (.zip) is [10.5281/zenodo.3607301](https://doi.org/10.5281/zenodo.3607301).

LENS

The NBMSI system at KU Leuven uses standard the Schneider Kreuznach 120mm LS f/4.0 Macro (serial TD002090). The standard applied aperture is f/16, this to keep the imaged surface in focus across the spectrum (365 – 940 nm).

FILTERS AND FILTER WHEEL

Filter wheel

The filter wheel carousel is the 'Intelligent Filter Wheel, IFW 3"', produced by [Optec Inc](#) containing 6 slots for 2 inch square filters. It is connected with the operating computer and is commanded by the Spectral XV software.

Filters

Five filters are mounted inside the filter wheel carousel leaving one slot open for normal (uninterrupted) reflection imaging. The filters are manufactured by [Thorlabs](#), their transmission % has been measured along the electromagnetic spectrum from 200nm up to 1800nm or 2200nm.

1. FGUV11 (UV band pass)

[Transmission data](#) by manufacturer, corresponds to Schott Glass UG11.

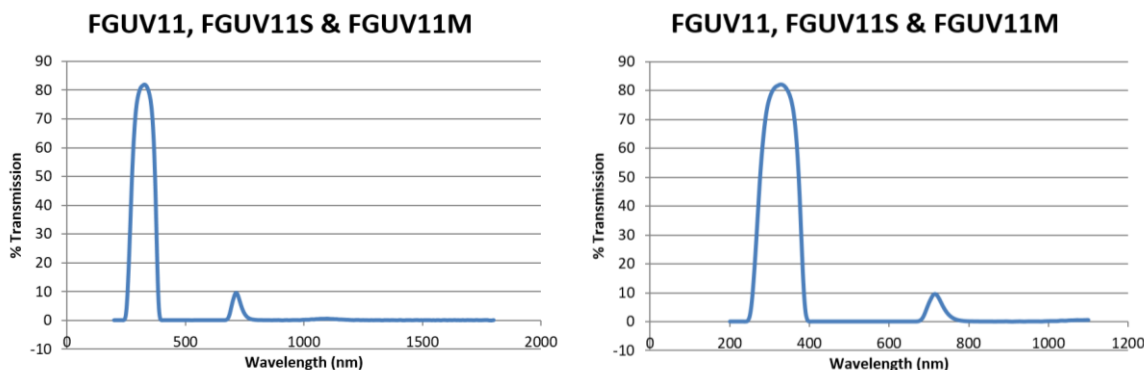


Fig. 3 – left: 200-1800nm; right: 200-1100nm (from www.thorlabs.com)

NOTE 1: The highest transmissions top just above 80%, from 310-340nm.

NOTE 2: From 685nm to 760nm the transmission % is above 1%, with a top above 9% for 710-720nm; depending on spectrum of emitter this can affect results during long(er) exposure times.

2. FGL435 (violet long pass, > 435 nm)

[Transmission data](#) by manufacturer, corresponds to Schott Glass GG435

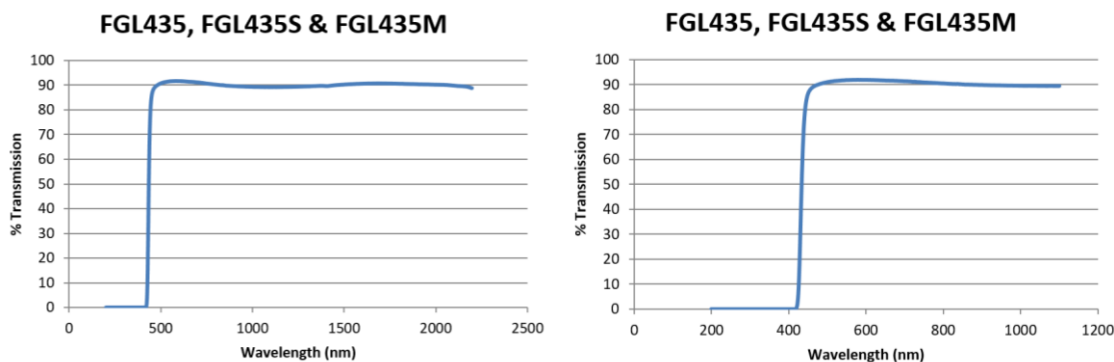


Fig. 4 – left: 200-2200nm; right: 200-1100nm (from www.thorlabs.com)

NOTE 1: transmission % at 420nm is 0,35483%, at 430nm 28,29404%, at 440nm 74,59118%, at 450nm 86,12728%.

3. FGL515 (green long pass, > 515 nm)

[Transmission data](#) by manufacturer, corresponds to Schott Glass OG515

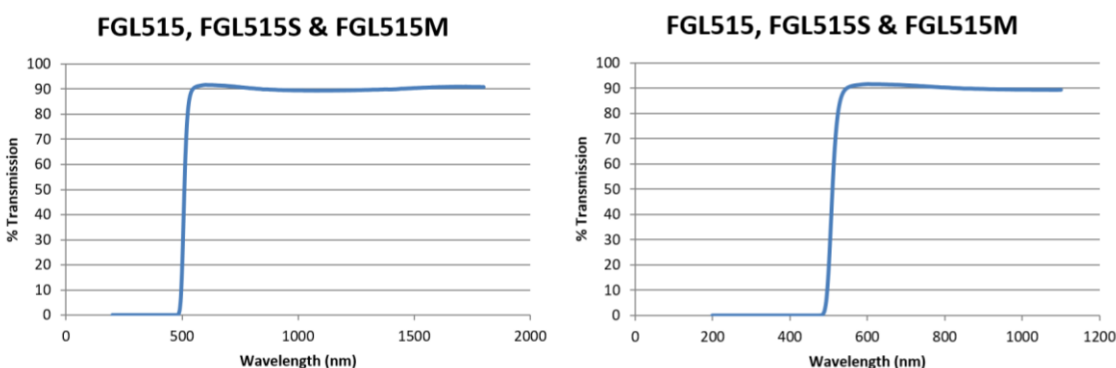


Fig. 5 – left: 200-1800nm; right: 200-1100nm (from www.thorlabs.com)

NOTE 1: transmission % at 490nm is 2,009189%, at 500nm 17,485076%, at 510nm 49,375509%, at 520nm 74,080543%, at 530nm 84,979313%, at 540nm 88,910648%.

4. FGL590 (red long pass, > 590 nm)

Transmission data by manufacturer, corresponds to Schott Glass OG590

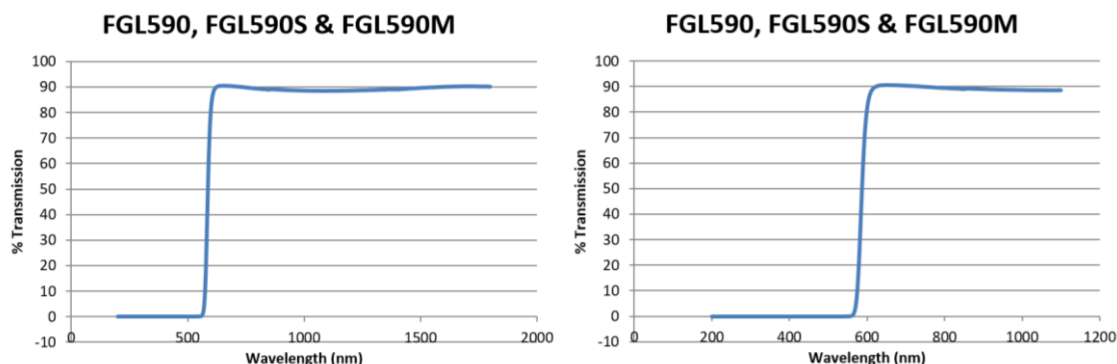


Fig. 6 – left: 200-1800nm; right: 200-1100nm (from www.thorlabs.com)

NOTE 1: transmission % at 570nm is 3,350253%, at 580nm 23,887793%, at 590nm 60,164501%, at 600nm 81,143515%, at 610nm 87,886484%, at 620nm 89,803653%.

5. FGL715 (IR long pass, > 715 nm)

Transmission data by manufacturer, corresponds to Schott Glass RG715

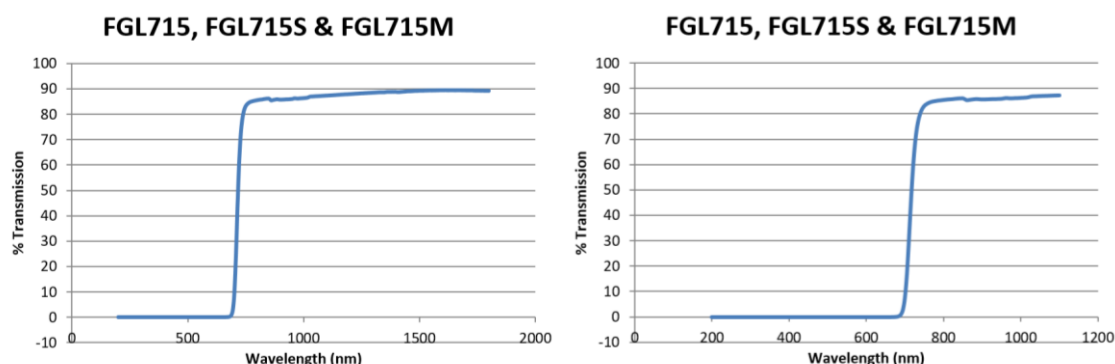


Fig. 7 – left: 200-1800nm; right: 200-1100nm (from www.thorlabs.com)

NOTE 1: transmission % at 690nm is 1,061519%, at 700nm 7,457874%, at 710nm 28,917544%, at 720nm 56,270572%, at 730nm 73,13305%, at 740nm 80,330764%, at 750nm 83,180318%.

Table 1 – Filters as mounted in the KU Leuven NBMSI system filter wheel

Filter	Code	Position	Description	Label Spectral XV
none	"N"	0	Empty position in filter wheel carousel	no label
FGUV11	"U"	1	UV band pass (\wedge 275 - 375 nm) ¹²	BP365
FGL435	"V"	2	Violet long pass (> 435 nm)	LP400
FGL515	"G"	3	Green long pass (> 515 nm)	LP515
FGL590	"R"	4	Red long pass (> 590 nm)	LP590
FGL715	"I"	5	IR long pass (> 715 nm)	LP715

LED PANELS

Next to the camera, lens and filter wheel combo, the Spectral XV acquisition software drives two identical EurekaLight Multi-Spectral Illuminators. The light panels count 16 different narrow band LED emitters mounted and clustered in a metal casing (i.e. 8 units clustering one set of 16 LED emitters, thus in total 8x16 LED emitters). The LED emitters have been manufactured by [LED Engin](#) and [Lumileds](#).

Diffuser film and clear acrylic covers, mounted in front of the clusters of LED emitters and lenses, form the output windows of the panels. Diffuser film is attached to the output windows and is manufactured by [Lee Filters](#), the part number is [250](#).¹³ The diffuser film smooths the output of the lensed LED emitters, is non-fluorescent, and has a negligible filtering effect. Tests have shown the acrylic material forming the output windows and the polycarbonate lens material have an effect on the output of the 385nm LED emitter (below Lumileds: LHUV-0380-A040), as the front window, only at this wavelength, will itself fluoresce and therefore shifts the output spectrum to a longer wavelength range (i.e. from the originally emitted 385nm to approximately 400nm). The even light distribution is assured as each of the 8 units spread across the inside of the light panel (see Fig. 8) include all of the 16 narrow band light emitters.

The light panels are connected with the operating computer and commanded by the Spectral XV software.

The identical EurekaLight panels used in the Spectral XV system at KU Leuven (since 2019) with their manufacturer information and software IDs are:

- Light Panel 1 (left)
 - Manufacturer: Equipoise Imaging, LCC – Ellicott City, MD, USA
 - Product Name: EurekaLight Multispectral Illuminator

¹² The transmission % of this filter is maximal between 310-340 nm (just above 80%); at 365 nm the transmission is 66%.

¹³ Type 1 diffuser in front of 365nm (LED Engin LZ1-00UV00); Type 2 diffuser in front of all other LEDs.

- Model: 1806
- Year of production: 2018
- ID1: 0205
- ID2: 0205_20181208_eqpi (Device ID)
- ID3: Left-0205-Light1 (Device Name)

➤ Light Panel 2 (right)

- Manufacturer: Equipoise Imaging, LCC – Ellicott City, MD, USA
- Product Name: EurekaLight Multispectral Illuminator
- Model: 1806
- Year of production: 2018
- ID1: 0206 (on panel)
- ID2: 0206_20181208_eqpi (Device ID)
- ID3: Right-0206-Light2 (Device Name)

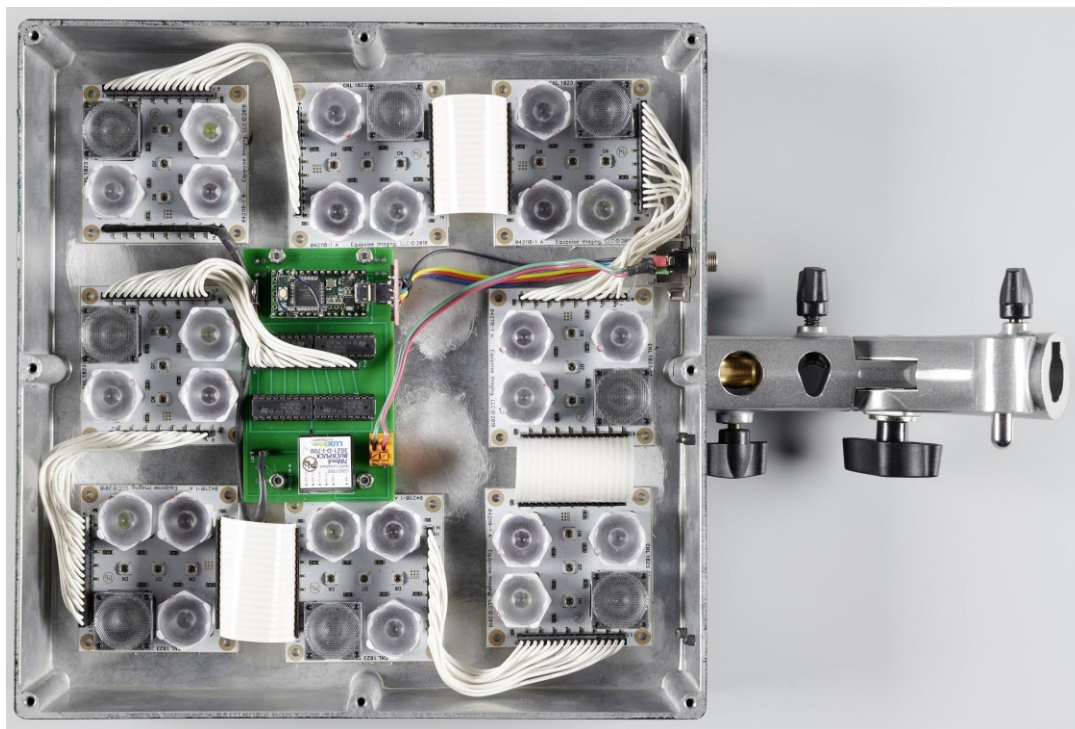


Fig. 8 – inside a Eureka light panel (at KU Leuven Libraries)

Below the table lists per applied set of narrow band LEDs in the EurekaLight panel the manufacturer and product/part number; the technical product datasheets can be found via the manufacturers or is included in the dataset of <https://doi.org/10.5281/zenodo.4548090>¹⁴.

¹⁴ Always take in mind to consult the newer versions of this same document, they will have another DOI.

Table 2 – Narrow band emitters as mounted in the Eureka light panel

	Narrow band	Manufacturer	Product/Part number
1	^365nm	LED Engin	LZ1-00UV00
2	^385nm	Lumileds	LHUV-0380-A040
3	^410nm	Lumileds	LHUV-0405-A065
4	^420nm	Lumileds	LHUV-0420-0650
5	^450nm	Lumileds	LXZ1-PR01
6	^480nm	Lumileds	LXZ1-PB01
7	^510nm	Lumileds	LXZ1-PE01
8	^530nm	Lumileds	LXZ1-PM01
9	^550nm	Lumileds	LZX1-PX01
10	^600nm	Lumileds	LXZ1-PL01
11	^630nm	Lumileds	LXZ1-PD02
12	^640nm	Lumileds	LXZ1-PD01
13	^660nm	Lumileds	LXZ1-PA01
14	^740nm	LED Engin	LZ1-00R302
15	^850nm	LED Engin	LZ1-00R602
16	^940nm	LED Engin	LZ1-00R702

TX TRANSMITTING MODULE

The TX Transmitting Module for the NBMSI system at KU Leuven is used since the late Summer of 2020. The technical details by the manufacturer and software IDs are:

- Manufacturer: Equipoise Imaging, LCC – Ellicott City, MD, USA
- Product Name: Looking GLASS TX Multispectral Illuminator
- Model: 1905
- Year of production: 2020
- S/N: 24601
- ID1: 0302
- ID2: 0302_TX20190516-eqpi (Device ID)
- ID3: TX-0302-Light3 (Device Name)

The TX module is equipped with sets of **narrow band LEDs**. For each of the 8 selected spectral wavelengths (see table below) the set includes 4 LEDs; they are mounted across one side of an acrylic glass sheet. The LED type with the blue, green, amber and red wavelengths (i.e. table below 1-4) are K2 surface mount visible emitters with a side emitting lens. The LED type with the red/IR and IR wavelengths are surface mount emitters with a flat top lens. The **acrylic glass sheet** (platen) is of the type EndLighten (8 mm thickness) by Evonik and is composed of PMMA acrylic containing microscopic phase scattering dopants. Light injected into the panel along one

edge travels parallel to the surface of the platen across the full breadth of the platen due Total Internal Reflection (TIR). Light is emitted from the entire upper surface of the platen due to the internal dopant particles and texture of the upper surface that allow light at the top surface to escape the TIR condition. Software flattening may be used with captured images to reduce the light intensity gradient in the direction of light propagation across the breadth of the platen. On top of the acrylic glass sheet, i.e. the side oriented towards the camera, a **diffuser film** is added (Lee Filters, diffuser type #250: ½ white, clear), to maximize the uniform radiation of the light in the direction of the light sensor.

The technical product datasheets of the LEDs, acrylic glass sheet and diffuser film can be found via the manufacturers or is included in the dataset of <https://doi.org/10.5281/zenodo.4548090>¹⁵.

Table 3 – Narrow band emitters as mounted in the TX Transmitting panel

	Nominal central wavelength	Manufacturer	Product/Part number	Label
1	448nm (blue)	Luxeon	LXK2 PR14 Q00	448TXN
2	535nm (green)	Luxeon	LXK2 PM12 S00	535TXN
3	590nm (amber)	Luxeon	LXK2 PL12 Q00	590TXN
4	636nm (red)	Luxeon	LXK2 PD12 R00	636TXN
5	700nm (red-IR)	Marubeni	SMBB690D-1100	690TXN
6	780nm (IR)	Marubeni	SMBB780D-1100	780TXN
7	850nm (IR)	Marubeni	SMBB850D-1100	850TXN
8	940nm (IR)	Marubeni	SMBB940D-1100	940TXN

SPECTRAL XV SOFTWARE

The Spectral XV software, version 2.1.1.4 (R. B. Toth Associates LLC/Equipoise Imaging LLC) is an integrated capture package controlling the camera, lens, filter wheel combo and Eureka Light panels. Using Phase One's COPE (Capture One Processing Engine) library, the Spectral XV software allows streamlined image capture and metadata operations. It also performs preprocessing operations that result in final output images for visual or further quantitative analysis and visualization using Paleo Toolbox processing software provided by Equipoise Imaging, LLC.

An example of such an acquisition sequence (labelled as the 'KU Leuven Basic MS Sequence' - KULBMSS) and the applied automated file naming is found at <https://doi.org/10.5281/zenodo.4545384>¹⁶.

¹⁵ Always take in mind to consult the newer versions of this same document, they will have another DOI.

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MOBILITY

The setup of the NBMSI system is semi-fix. It has been installed in the Imaging Lab of the KU Leuven Libraries for day to day NBMS digitisation tasks, but it can also be used on location. All equipment is hand-held portable. The standard setup consists of a camera looking down, mounted on the automated Kaiser rePRO RSP copystand. In other constellations, the NBMSI system can be combined with conservation book cradles for imaging or any type of tripod and support systems allowing the camera to be positioned in any angle directed to the digitised surface.

Contact:

digitalisering@kuleuven.be, implementation KU Leuven – 3Pi Project NBMSI system
lieve.watteeuw@kuleuven.be, academic coordinator KU Leuven 3Pi Project

Difference between version 1.0.0 (<https://doi.org/10.5281/zenodo.3607302>) & version 1.1.0

- Typos and orthography.
- Adding the documentation on the TX Transmitting Module.

The DOI for all versions of this document (.zip) is [10.5281/zenodo.3607301](https://doi.org/10.5281/zenodo.3607301).