WEAVE
Design of the calibration unit for the WEAVE multi-object spectrograph at the WHT

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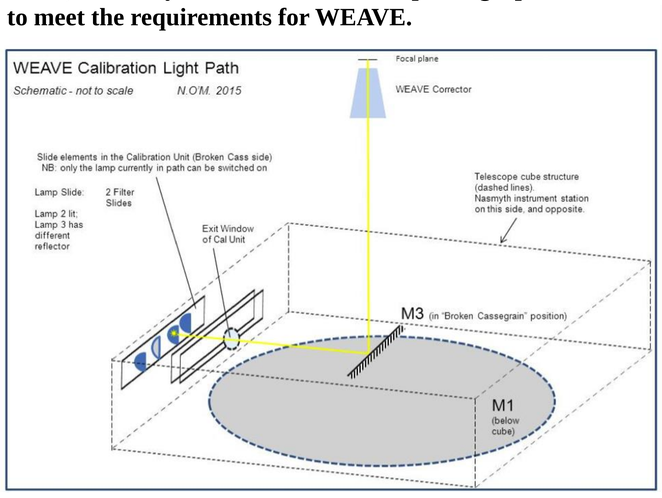
ABSTRACT

WEAVE is the next-generation spectroscopic facility for the William Herschel Telescope (WHT), offering multi-object (1000 fibres) and integral-field spectroscopy at two resolutions (R ~ 5000, 20000) over a 2-deg field of view at prime focus. WEAVE will (mainly) provide optical follow up of ground-based (LOFAR) and space-based (GAIA) surveys. First light is expected towards the beginning of 2018.
Here, we describe the calibration unit, which will be adapted from an existing unit for the AF2+WYFFOS spectrograph (WEAVE's precursor) at the WHT. We summarise the results from a thorough characterisation of current performance (e.g. intensity, stability and focal-plane coverage of illumination as a function of lamp type and wavelength). We then set out our plans for upgrading the unit and its control systems to meet the WEAVE science and operational requirements.
We conclude from this assessment that the upgraded AF2+WYFFOS calibration unit will meet the requirements for WEAVE.
The design of the WEAVE calibration unit is now complete.

Overview of calibration unit

The design of the WEAVE calibration module is based on the hardware existing installed in the WHT, currently in use for WYFFOS spectrograph. The current calibration unit is being adapted to meet the requirements for WEAVE.



- ✧ The lamps in the calibration unit illuminate the field-of-view at WHT Prime Focus via the tertiary mirror (M3). Light is thus fed into the WEAVE fibres placed on the focal plane.
- ✧ Exposures obtained with these lamps are required to calibrate the science data, and also to monitor the long-term instrument quality.

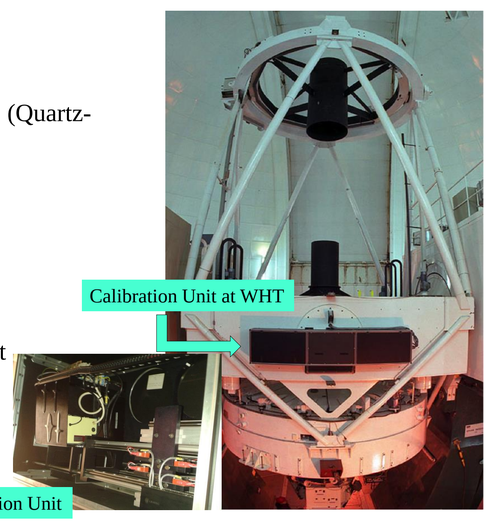
Infrastructure

The calibration unit consists of:

✓ **Lamp slide with 4 parabolic reflectors:**
- 1 permanently occupied by **continuum QTH** (Quartz-Tungsten-Halogen) lamp
- 1 permanently occupied by **ThAr** lamp
- 2 reflectors for any of **Ne, He, Hg, Zn or Cd**

✓ **2 filter slides with 6 positions:**
- Neutral density filters (ND = 0.5, 1, 2, 3)
- Colour filters
- Dark filter to prevent lamp flux spilling of the unit

✓ Tertiary mirror (M3) pointing to "Broken Cassegrain" aperture as long as needed without interfering with observations



New control system

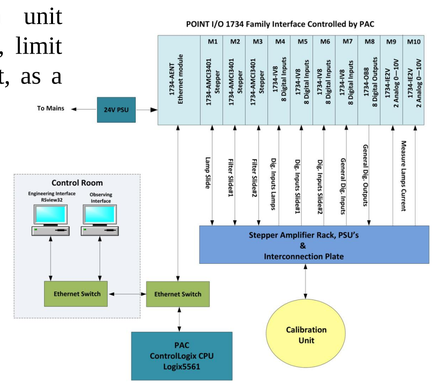
✓ The control of the calibration unit mechanisms will be integrated into the WEAVE spectrograph's PAC (Programable Automation Controller).

- A remote sub-controller integrates all calibration unit mechanisms and support equipment (encoders, sensors, limit switches, etc.) with the spectrograph PAC, via Ethernet, as a single controller, without extra hardware.

Allen Bradley 1734 Point I/O remote controller rack

Calibration unit engineering Interface

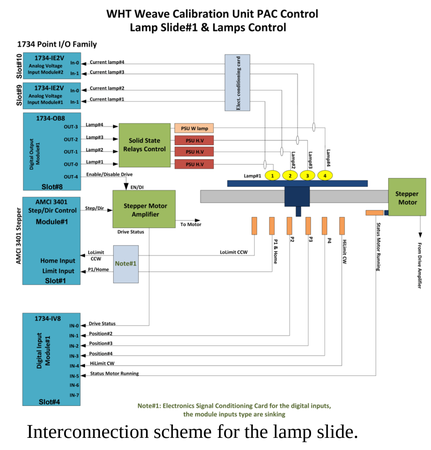
WEAVE Calibration Unit PAC Control



✓ Communication with Observatory Control System (OCS) through the standard PLCIO library:

- OCS maps PAC memory, reads and write the data: the PAC code is not responsible for updating the upper layers, just for updating the internal data structures that will be read by the higher-level software, both the OCS and/or the engineering interface.

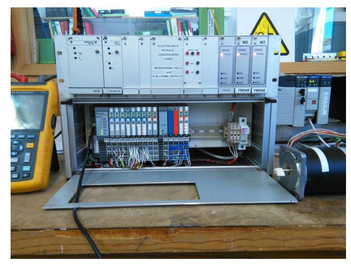
Mechanism speed



Interconnection scheme for the lamp slide.

By implementing a new control strategy for the stepper motor, we have increased the speed of calibration unit mechanisms by a factor of 5 and improved performance, while keeping 100% of the hardware.

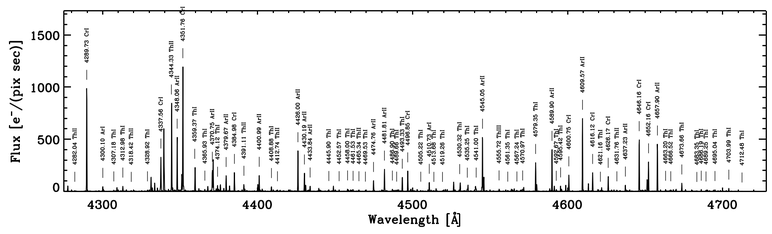
- ✓ Expected achievable speed ~40 rev/sec (linear speed ~0.20 m/s).
- ✓ **Expected maximum time for any slide movement < 20 seconds**, with 1 second for ramp up and ramp down of the motor speed.



View of the remote rack + PAC + dummy motor: test setup in the laboratory.

Wavelength coverage

Example of arc map for the ThAr lamp (R = 18000).



Summary of lamp suitability for each WEAVE spectroscopic mode:

WEAVE setup	WEAVE spectral range (Å)	Lamp option 1 (match requirements)	Lamp option 2 (almost match requirements)	Complementary lamps
Low-resolution blue arm	3660-6060	ThAr	---	Ne, He
Low-reasolution red arm	5940-9840	ThAr	Ne	Hg, Cd
High-resolution Blue 1	4040-4650	ThAr	---	---
High-resolution Blue 2	4730-5450	---	ThAr	Ne
High-resolution red arm	5950-6850	ThAr	---	Ne

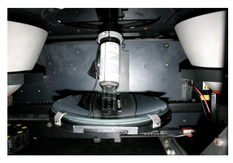
Our analysis of arc maps for all available arc lamps (ThAr, Ne, He, Hg, Zn, Cd) concludes that:

- ✓ **ThAr lamp is the most suitable arc lamp for WEAVE.**
  - >10 arc lines/100 nm for low-resolution
  - >10 arc lines/25 nm for high-resolution
- ✓ Ne lamp useful at the red in low-resolution.
- ✓ **ThAr and Ne lamps provide satisfactory calibration for WEAVE at all wavelengths.**

Focal-plane illumination

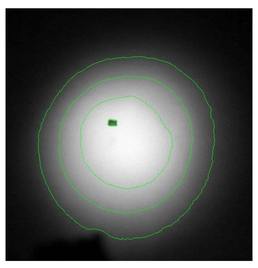
- ✓ **Radial variation in illumination is < 50% over the 40 cm diameter field required by WEAVE for QTH, Ne, He and Hg lamps.**
- ✓ **Exposure times < 30 sec provide the required Signal-to-Noise for QTH, Ne, He, Hg and Cd.**

❖ **The principal issue with conventional hollow-cathode (HC) ThAr lamp:**
- Intrinsically faint, especially in the blue lines => long exposure times
- Difficulty adjusting lamp for uniform illumination over the WEAVE 2-deg field => outer half of the field insufficiently illuminated



ThAr lamp and special reflector installed in the calibration unit between other two conventional lamp reflectors.

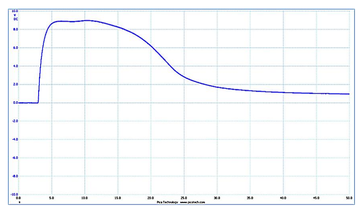
➔ **New ThAr lamp from Photron Ltd. (Australia) has been purchased for WEAVE, which allows an excitation current 4 times higher.** By careful adjustment of the lamp position within the reflector, we have found:
- ✓ Improves flux 3 fold (over conventional) => shorter exposure times.
- ✓ Illuminates the WEAVE 2-degrees field with the required uniformity.
- ✓ The reflector mount should undergo mechanical modifications to improve adjustability, stability and repeatability.

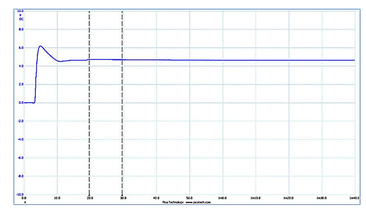


Beam of new ThAr lamp with optimal focus adjustement. Second contour is ~37 cm diameter and corresponds to 50% of the maximum flux

Repeatability of lamp intensity

The variation of lamp intensity with time was measured for all available lamps, including lamp switch-on times, brightness variations, warm-up times, and long term stabilization. Both integrated lamp flux and relative/total spectral arc line variation were analysed in detail.





Power-up response of the Hg (left) and the ThAr (right) lamps with output signal from the photodiode (arbitrary voltage scale) versus time (second).

- ✓ Largest variations in flux is typically in the first 30 sec after switching on, particularly in the Hg, Cd lamps.
- ✓ ThAr, Ne practically do no need warming.
- ✓ Small variation (< 10%), after warm-up, in relative line intensity over periods 15-20 minutes.

CONCLUSIONS

The design of the WEAVE calibration module is now complete. It is based on the existing mechanisms currently installed at the WHT in use for AF2+WYFFOS. An exhaustive assessment of the current performance of the unit has been carried out, concluding that after some upgrades (new control system, new control strategy, new lamps) the module will meet the WEAVE science and operational requirements.