A laser frequency comb to support precision radial velocity science with SALT's High-Resolution Spectrograph

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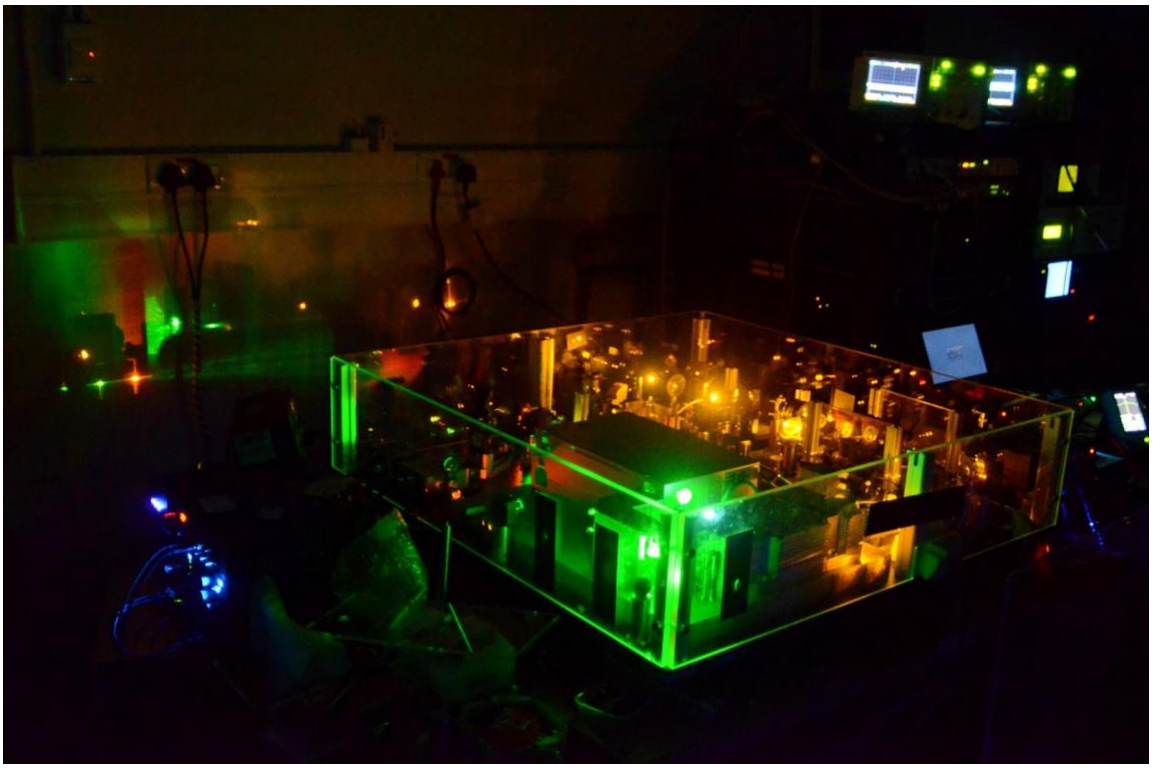


Project Background:

SALT's high-resolution spectrograph (HRS) is a general-purpose facility instrument that serves the SALT user community's echelle spectroscopy needs with its low (R~15k), medium (R~40k) and high (R~65k) resolution modes (known as LR, MR and HR, respectively). The HRS was also equipped with a fourth, specialist, high-stability (HS) mode specifically designed to support exoplanet science. It makes provision for employing either an iodine gas

absorption cell, or the simultaneous injection of thorium-argon arc light into the HS calibration fibre, to meet the wavelength calibration demands of precision radial velocity (PRV) work in the few m/s range. SALT has been working towards making these capabilities available to our users over the past few years.

As exoplanet researchers around the world seek to detect minute radial velocity (RV) signatures (Earth imposes a 9 cm/s wobble on the Sun's motion!), the tools of the trade have had to evolve. Laser frequency combs (LFCs) are among the state-of-the-art calibration devices involved in advancing this technically-challenging field and hence the most sophisticated current and planned PRV instruments all include LFCs. While SALT and its HRS will never be at the tip of the PRV spear, we do intend to identify and occupy an appropriate niche within the exoplanet business. To this end, we have a project underway to develop a bespoke LFC for the Red (550-890 nm) channel of the HRS, along with the requisite PRV data pipeline, to enable the HRS to reach the 1-2 m/s level.

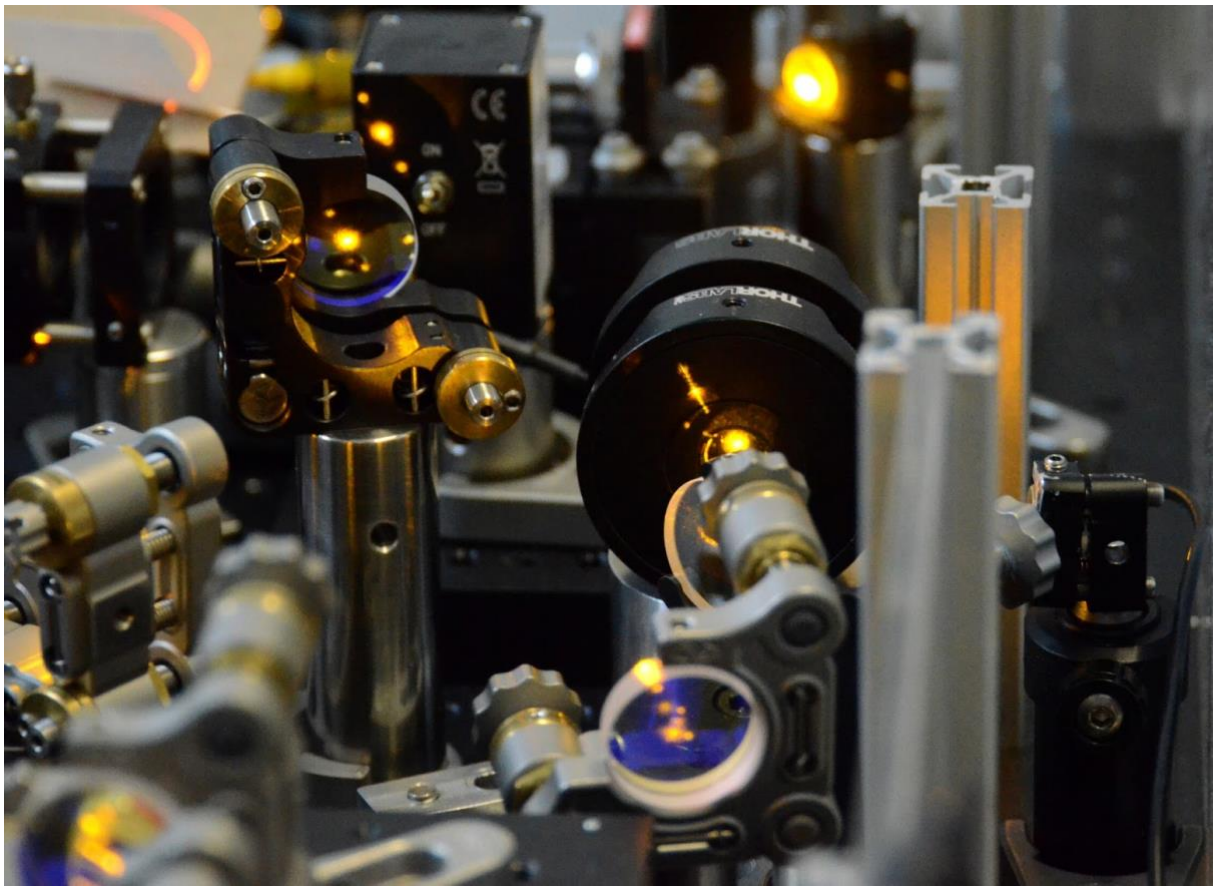
The LFC development hinges on a collaboration with researchers in the UltraFast Optics group at Heriot-Watt University (HWU) in Edinburgh, whom we first worked with in 2016. Back then they temporarily installed an experimental LFC at SALT and its operation was tested with the HRS over the course of a few months. This was an extremely valuable exercise for both camps, laser physicists and astronomers alike learned a great deal and it has been a goal of ours ever since to permanently add an LFC to the HRS.

With the project funded, as well as LFC and PRV pipeline development contracts progressing well, we are keen to bring in a PhD student to participate in this exciting initiative. The project is nearing the end of its procurement phase, with most of the components having been manufactured and/or delivered to the Observatory. The SAAO mechanical workshop has machined parts for the comb chassis and SALT Tech Ops staff are building electronics modules and power supplies for the system. The plan is then for the HWU team to travel to SALT in August 2023 to carry out the integration and begin commissioning of the LFC. In the meantime, work is underway in parallel on the PRV data reduction pipeline for the HRS HS mode.

Project Description:

The PhD will largely focus on instrument development, but will also include an exoplanet research component to demonstrate the HRS's new capabilities. The

practical instrumentation aspects will include lab work (a few months in the laser labs at HWU, learning about LFC technologies and all of the associated equipment), participation in the LFC integration at the telescope, involvement in the engineering and on-sky commissioning, as well as the characterisation, documentation and technical support of the LFC as it gets incorporated into normal operations at SALT. The research section of the project will involve SALT HRS observations with the LFC, and draw on the new PRV pipeline. The hardware is due to be ready before the full pipeline becomes available and there will likely be a need for iterative refinement of the software beyond the nominal two-year pipeline development timeframe. This would therefore be a good opportunity to get to grips with the various data reduction and analysis processes, as well as the art of writing robust code (in Python) for external users.



Useful Links:

SALT HRS SPIE Conference Papers:

- 2022 HRS HS Mode: https://cloudcape.saao.ac.za/index.php/s/JhdTpYLmiTge3Sh
- 2020 HRS HS Mode: https://cloudcape.saao.ac.za/index.php/s/jtFREgy1SdIxMO1

- 2018 HRS Iodine Cell: https://cloudcape.saao.ac.za/index.php/s/JI1YV94WH4YLvjj
- 2016 LFC Field Trial: https://cloudcape.saao.ac.za/index.php/s/9OsUdby2LIJGos4
- 2014 HRS Commissioning: https://cloudcape.saao.ac.za/index.php/s/eTIRpaNlRsRTO7Q

Selected LFC Papers:

- 2017 Review (McCracken): https://cloudcape.saao.ac.za/index.php/s/1Tk0G2ktVuVVxe7
- 2017 SALT Optics Express: https://cloudcape.saao.ac.za/index.php/s/goPbtMfDXiooECf
- 2010 Review (Diddams): https://cloudcape.saao.ac.za/index.php/s/ocBmCyARld83EfG

SALT LFC Blog Posts:

- https://saltastro.blogspot.com/2016/04/a-laser-frequency-comb-at-salt.html
- https://saltastro.blogspot.com/2016/04/getting-lfc-set-up.html
- https://saltastro.blogspot.com/2016/04/so-how-do-these-things-work.html
- https://saltastro.blogspot.com/2016/04/a-great-analogy-to-explain-lfc.html
- https://saltastro.blogspot.com/2016/05/first-light-on-sky-observations-with-lfc.html