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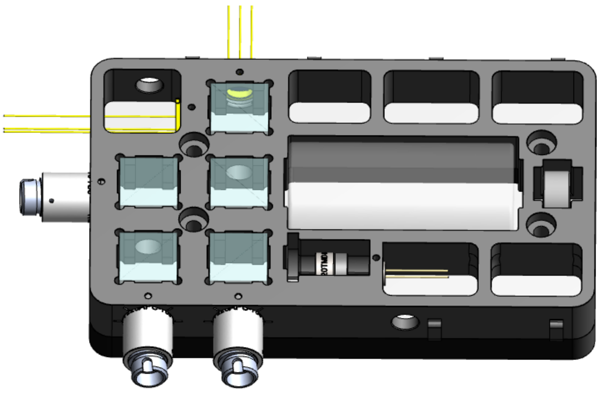
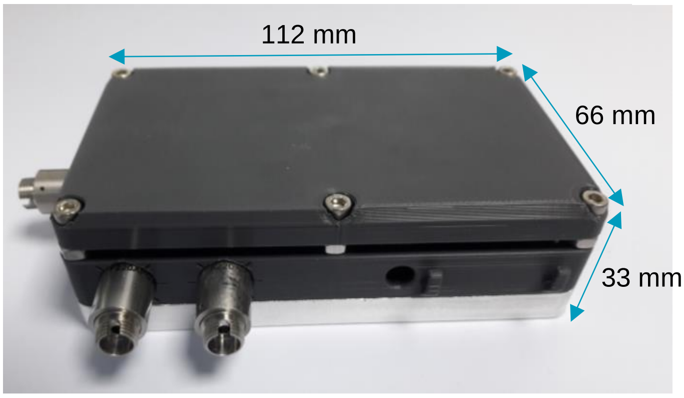
Compact Spectroscopy Apparatus

Overview

We have designed a compact, highly stable spectroscopic apparatus based upon an additively manufactured PLA chassis combined with industry-standard optical components. The device has fibre-coupled inputs and can perform saturated absorption spectroscopy with two laser inputs simultaneously, using an integrated atomic vapour cell. Optionally, it may also generate an optical beat note between one of the inputs upon which it performs vapour spectroscopy and a third laser input.

The device is patent published in the UK (GB2590352).





Prototype device with measurements (130 x 90 x 32 mm when including protruding spectroscopy components). Mass = 280 grams.

If only the two vapour spectroscopy signals are required, assembly of the device takes 1–2 hours and does not require specialist skills other than some simple soldering for the photodiodes. If the optical beat note is required then this likely adds around another 2 hours per unit, and the assembler will require laser safety training and some experience with optics.

There is significant scope to modify and/or augment the design to improve performance or add additional functionality. The inventors are happy to discuss the possibilities for further development with any interested parties. The layout of the device and the production method employed mean that it can easily be adapted to use parts with different dimensions or customised to suit end-user requirements. In particular, we expect that there may be a market for a simplified, smaller version of

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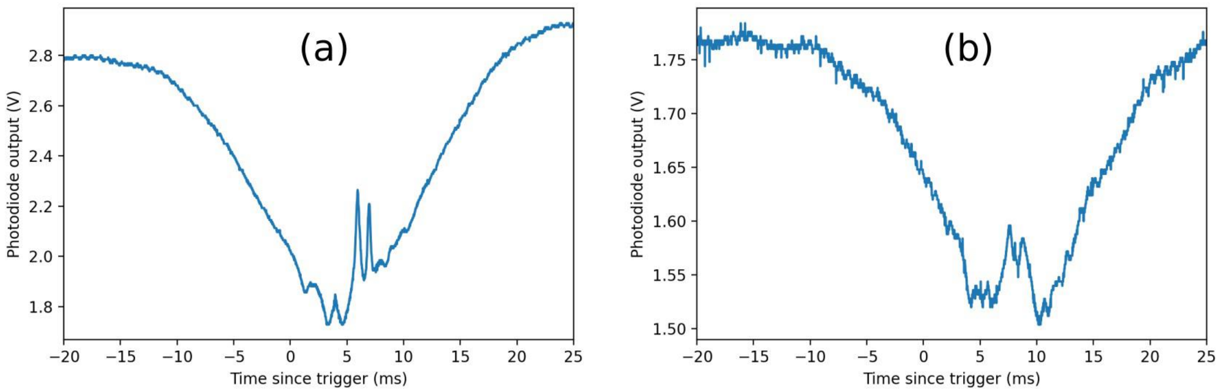
the device that only performs the two Doppler-free spectroscopy functions and does not generate an optical beat note

One notable feature of the device is that light from two different input lasers is spatially overlapped in the atomic vapour cell in orthogonal polarisation states. This was done as an aid to compactness, and to allow sharing of optical components and thereby reduce overall size and cost. However, we have also demonstrated that this technique allows significant enhancement of the resulting spectroscopic signals – see our preprint publication (Cooper, Madkhaly et al. 2021). The article is in the peer-review process and peer-reviewed publication will follow shortly.

The device contains a number of unique design features that facilitate installation and alignment of the optics contained within and prevent damage being caused to the optically active surfaces. The basic design principle, together with some transferable features of the optics slots, could be deployed to produce a much wider range of optical systems. Our recent work on developing such systems has attracted strong interest from the community, with a recent publication in PRX Quantum (Madkhaly, Coles et al. 2021) and an article in Physics magazine "3D-Printed Components for Cold Atoms" (Physics 2021).



An example of spectroscopy signals resulting from simultaneous presence of light from both cooler and repumper lasers in the vapour cell. (a) shows the results of Doppler-free spectroscopy on the cooler transition while light close to resonance with the repumper transition is present, and (b) shows the corresponding situation with the roles reversed. For full details of how dual-frequency spectroscopy works, and its benefits, see our publication (Cooper, Madkhaly et al. 2021).

References

Cooper, N., S. Madkhaly, D. Johnson, D. Baldolini and L. Hackermüller (2021). "Dual-frequency Doppler-free spectroscopy for compact atomic physics experiments." arXiv:2106.11014v2 [physics.atom-ph].

Madkhaly, S. H., L. A. Coles, C. Morley, C. D. Colquhoun, T. M. Fromhold, N. Cooper and L. Hackermüller (2021). "Performance-Optimized Components for Quantum Technologies via Additive Manufacturing." PRX Quantum **2**(3): 030326.

Physics (2021). 3D-Printed Components for Cold Atoms. Physics, American Physical Society.

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Specifications

Filling	Alkali atoms
Optical Input Configurations	3x SM optical fibres (polarisation maintaining)
Input Power Range	0.5 to 5 mW per beam
Supported Locks	2x current modulation, 1x optical beat
Doppler Subtraction	Yes
Response Bandwidth	10 kHz (spectroscopy), 500 MHz (beat)
Temperature Stabilisation	Not currently, could be added
Photodetection	Silicon photodiodes
(Housing) Dimensions	112 x 33 x 66 mm
Input Fibre Termination	Standard patch cable connector
Reference Cell Temperature (Max.)	40 °C (estimate)
Dimension of gas cell	25 mm dia. cylinder, 50 mm long
Electronic Outputs (BNC Sockets)	Bare photodiode pins

The total cost of the optical components required (at retail prices) is £1,650. This reduces to only £1,100 if the beat note is not required. The manufacturing cost of the chassis and base plate is very low – though the exact price may vary between processes and suppliers, it amounts to <£100 per unit. See separate component list for a full breakdown of optical components, suppliers, and prices.

Components:

Spectroscopy only

- Non-polarising beam splitter (1)
- Polarising beam splitter (2)
- Large area photodiodes (2)
- Mirror (1)
- Fibre Coupler (2)
- Rb vapour cell (1)

Beat signal

- Fast photodiode (1)
- Non-polarising beam splitter (2)
- Fibre Coupler (1)
- Polarising filter (1, optional)

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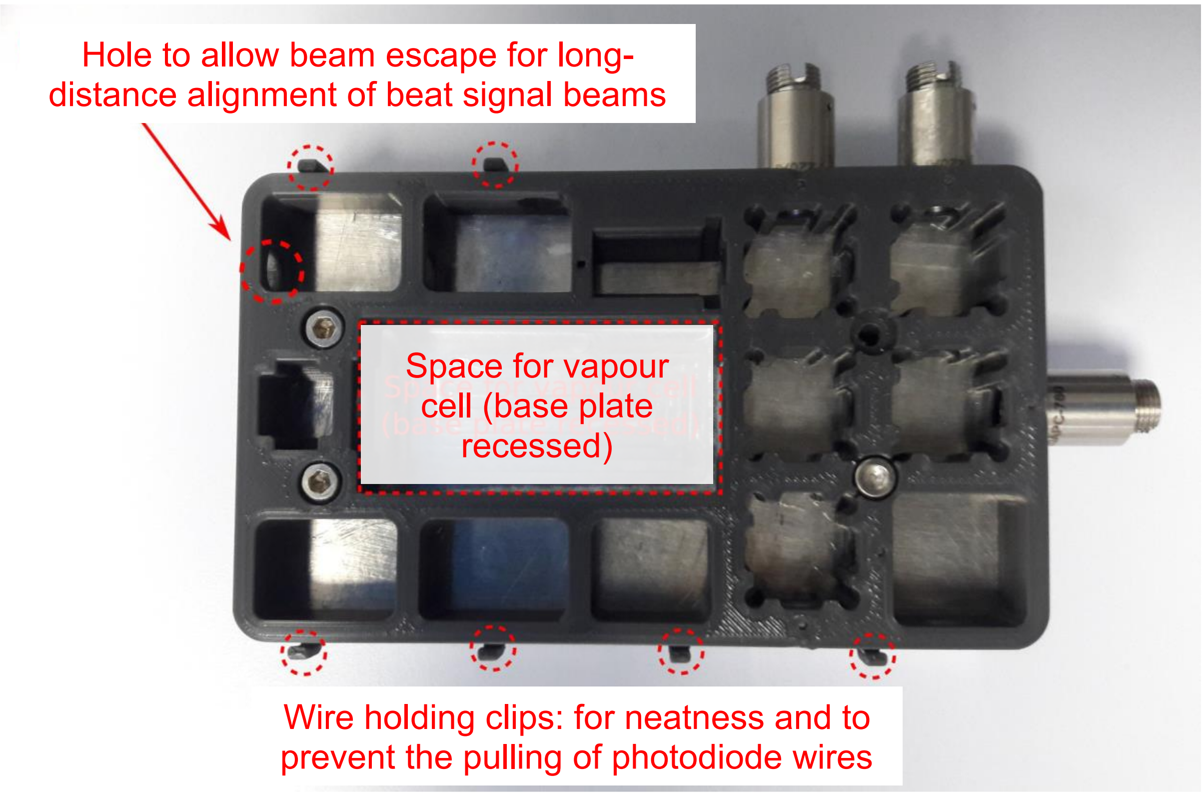
Additional Images

Below, we give some annotated images of the device and show the output signals resulting from vapour cell spectroscopy on Rubidium 85 atoms, in addition to an optical beat note generated at a range of frequencies up to 1 GHz.



The AM mount secured to an aluminium baseplate, with only external fibre collimators inserted. Note the unique shape of the slots for beamsplitter cubes, which provide superior alignment accuracy and avoid scuffing of optically-active surfaces.

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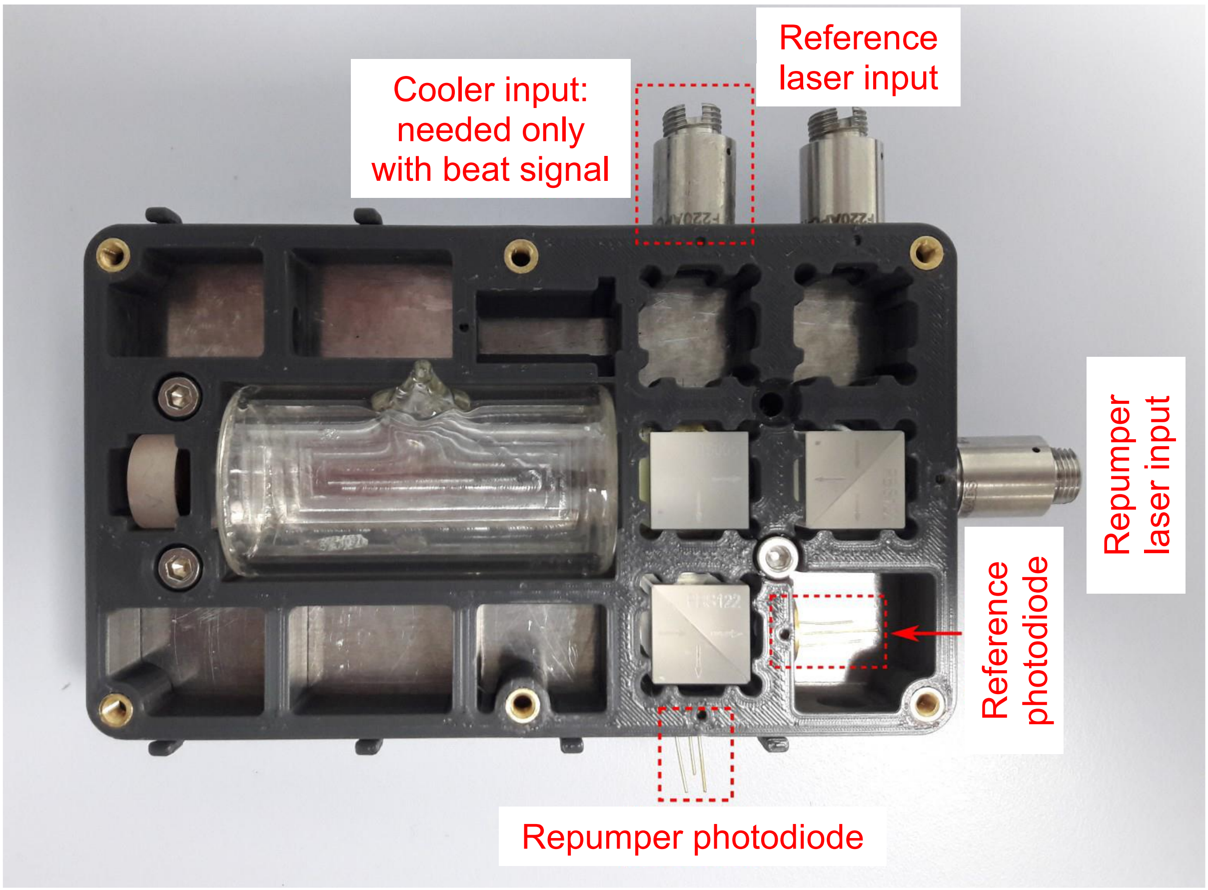
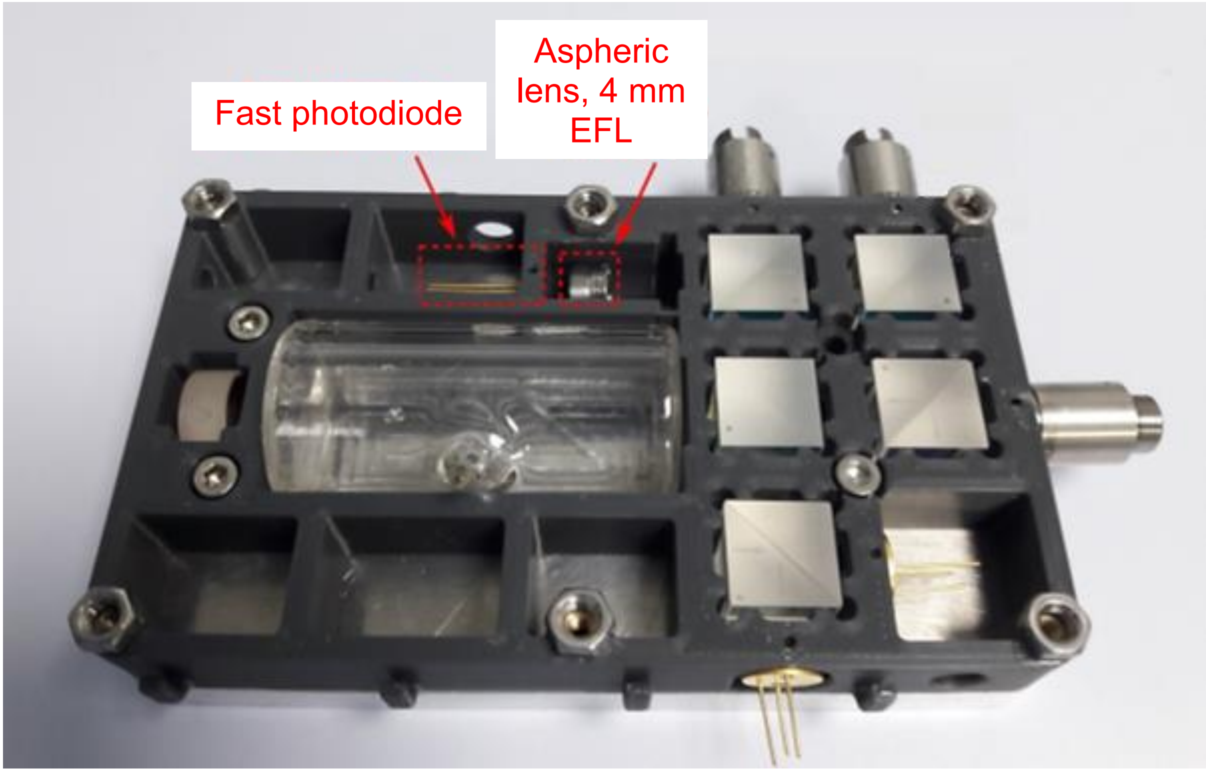


The device populated for simultaneous Doppler-free spectroscopy on the cooler and repumper transitions of the Rb D2 line. Note that one additional fibre collimator is present in this picture which is not required for this function.



The device containing the additional optics required for beat signal generation, as well as the original spectroscopic functions.

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