HP5065A Super upgrade

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The HP5065A has the frequency stability characteristics over time that place it among the best, commercial grade, Rubidium frequency standard ever built.
The challenge that many hobbyists are accepting is to further improve his performance.

One of the most interesting experiences has been to Corby Dawson(2) that installed, between the source of rubidium beam and the cell, a band pass filter to eliminate the visible emission that does not serve the the PLL loop, and then is "read" by the photo sensor as a superimposed noise. The result was a lower phase noise and an improvement in the short and medium term frequency stability.

see: http://leapsecond.com/corby/Super-5065A-Project.pdf

The improvement is based on lower noise of the detected rubidium signal.
A significant driver of the overall stability performance of the HP5065A is the rubidium signal-to-noise (S/N) ratio. The noise component in this ratio is in large part due to shot noise generated by unused or excess light that reaches the photo detector. The Rubidium Isotope (38) gas vapour lamp is the greatest contributor to this noise effect. Optical filtering can be effective in reducing the amount of unused light reaching the photo detector.

The placement of a 780nm optical band pass filter in the emission path is very effective in preventing the out of band spectra from reaching the photo detector and generating undesirable shot noise.

Typical ADEV improvement

Seconds	Before	After
1	1.4x10-12	4.0x10-13
10	4.0x10-13	2.1x10-13
100	1.2x10-13	6.0x10-14

Note: C.Dawson measurements

The filter must have a low in band attenuation in and be cut to the 780nm that is the main emission frequency of the Rubidium. The filter used is manufactured by Edmund Optics, 25mm Dia., Hard Coated OD 4 10nm Bandwidth. Its price in Europe, including VAT and delivery charges is approximately 250 Euros.

Edmund Optics Stock Number #65-178

To install the filter some changes to the lamp cover assembly are needed to be modified to lock the lens in place. Figure 1 shows the modified piece and the original.Figure 2 shows the filter inserted.

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Figure 3 shows the lamp module, assembled after the change. As you can see from the filter it has one face with a mirror finish and for this reason it is one-way so you have to install it in the correct direction.

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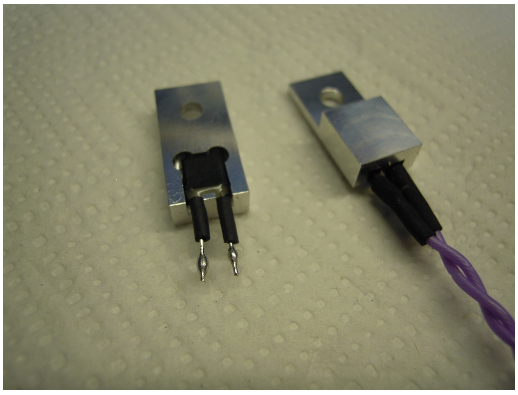
During the filter installation it is also implemented a temperature protection as one of the worst faults that can happen it is the fault of the lamp oven who normally works at about 93°C. In some cases, the failure of the heater raises the temperature to levels which the internal components and the lamp itself suffer disastrous effects.
As protection the installation of a thermal fuse is then recommended, a 2A and a melting point of 102°C. The fuse will be fixed via a locking tailored to this purpose. See figure 4.



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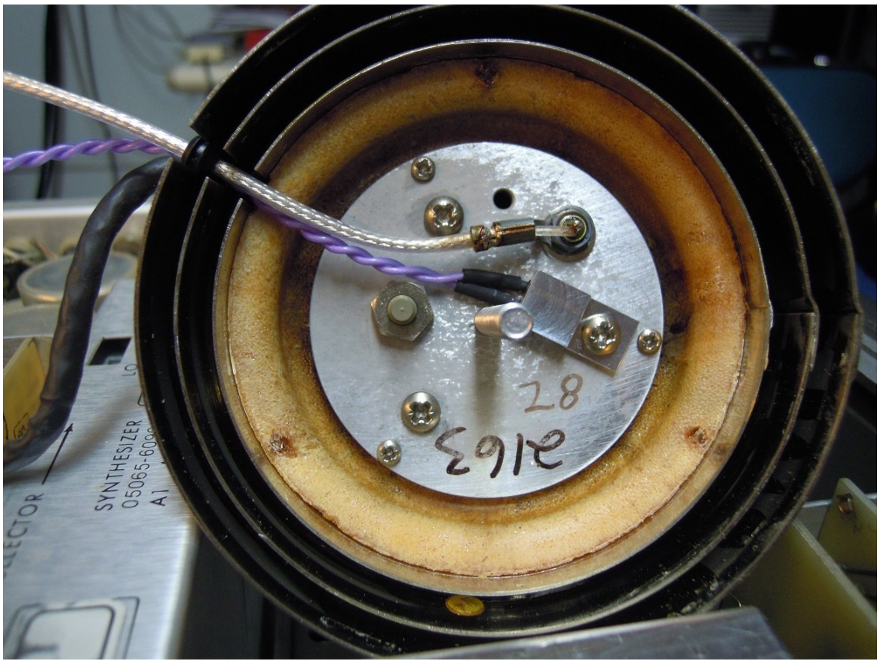

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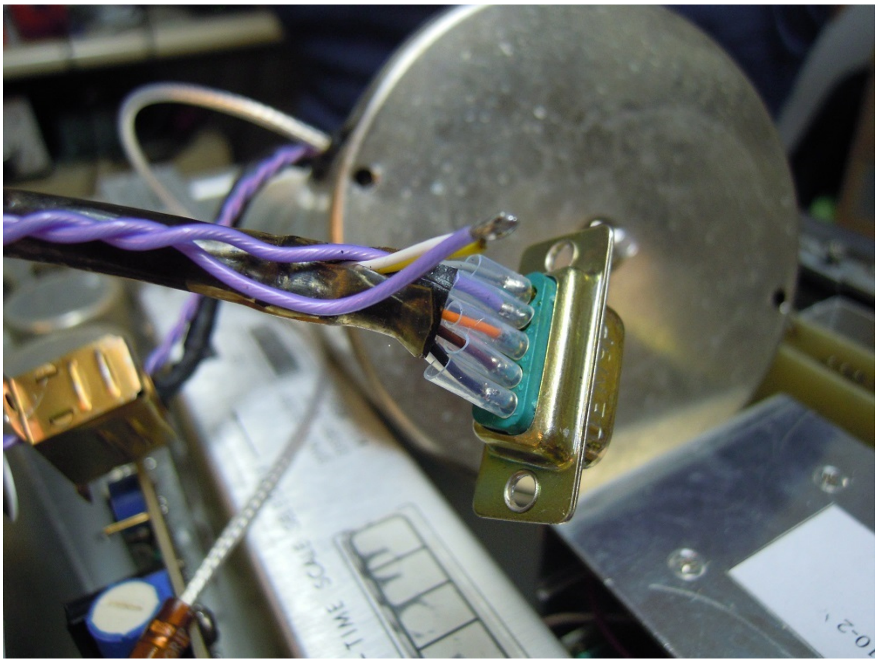
The fuse is connected through two twisted wires to not create an additional magnetic field that would affect the frequency stability of the standard, the wires, in addition, must be resistant to the working temperature, about 100°C.



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The wires of the thermal fuse will be connected in series to the power supplies of the two heaters in the P5 connector between the Yellow//White wires and the pin 4 of the connector were they are originally connected.

Once reassembled, is necessary proceed with the calibration to restore the correct operating frequency. After the warmup and the Logic Reset it is mportant to verify the new values about PHOTO-I and 2ND HARMONIC.

PHOTO-I will decrease considerably because the beam emission value of the lamp will not strike more the photocell while the level of the second harmonic can vary depending on the initial and final conditions of the lamp reflector. If the parable initially did not show traces of oxidation it will be noted an attenuation of about 20% of the level due to the in-band attenuation of the filter, while if the oxidations were significant and are removed in the phase of installation of the filter, it will be appreciated a signal level unchanged or greater than the pre-change conditions. The stability of the,before/after level of the second harmonic is also due to the greater width hole of the new filter fixing ring that compensates for the in-band attenuation of the filter.

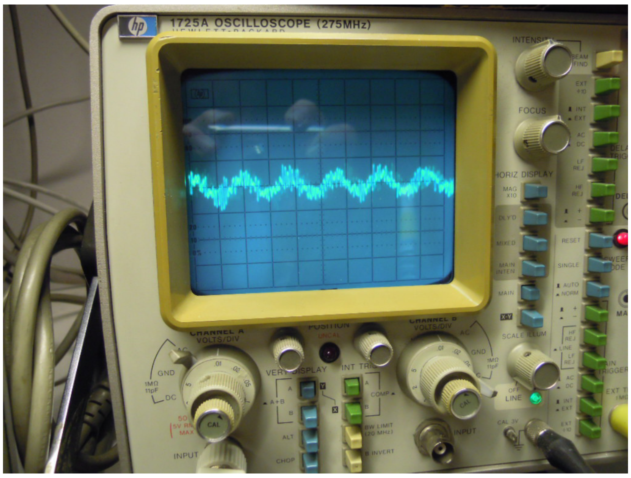
Example of measured parameters on three HP5065A

	HP5065A nr	BEFORE	AFTER
PHOTO I	1	25.5	9.5
	2	42	13
	3	36	11
2ND HARMONIC	1	28	36
	2	32	31
	3	40	46

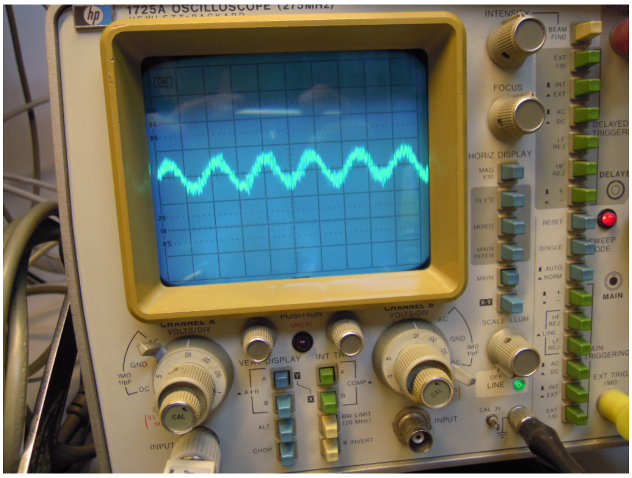
After installation of the filters in the first two HP5065A I have not had to change the A7 amplifier gain because the second harmonic was between 20 and 40, then the parameters recommended in the service manual.

S/N verification

An easy way to see the difference of the output signal from the first amplifier of the photodetector can be done simply by connecting an oscilloscope to A7 TP2. In the following pictures you can see the difference of the superimposed noise at 137Hz modulation before and after the change.



7 A7 TP2 before the upgrade



8 A7 TP2 after the upgrade

This is only an empirical test. The oscilloscope display show the 137Hz signal, the second harmonic and broadband noise.

An accurate measurement of the signal to noise ratio can be made following the instructions of the Service Manual chapter 5-26 page 5-13. HP recommends using a HP3581A, a selective voltmeter but you can use other tools such as the HP3561A that allows the use of simplifications.

An HP5065A under test show a value of 255 (HP say 250or more) as signal to noise ratio before the 780nm filter installation and after the upgrade the new s/n is 841.

The initial noise floor measured was around 300uV as HP write but with the filter it drop to 116uV.

The 137Hz signal level change from 76.5mV(before) to 97.6mV after the installation. We have to take account of a better parable reflection and a larger open area in front to the lamp due the new cover.

Frequency calibration

The installation of the Bandpass filter generates a frequency offset to be compensated by changing the value set in the synthesizer thumbwheel switch module. See page 3-10 and 3-11 of the HP5065A Rubidium Vapor Frequency Standard operating and service manual pn 05065-9041.

Typical example:

Initial settings :	9381	-112.423 e-10
Final settings:	9508	-88.401 e-10
Δ offset:		24.022 e-10

This alignment must be done by comparing the output frequency of the HP5065A (5MHz) with an external Frequency reference.

Note:

It must be remembered that a low signal to noise ratio can be caused by improper alignment of the RF matching network in the A3 Multiplier assembly or insufficent 137Hz phase modulation level (see step f of section 5-25, RF Alignment of the service manual). It is therefore recommended to do this verification.

"HP5065A Super" or "HP5065B" is the names proposed by Tom Van Baak for this up-grade view of the excellent results obtained.

Reference:

(1) *34th Annual Precise Time and Time Interval (PTTI) Meeting*
GPS CLOCKS IN SPACE: CURRENT PERFORMANCE AND PLANS FOR THE FUTURE
Mr. Todd Dass, Mr. Gerald Freed, Mr. John Petzinger, Dr. John Rajan

(2) Corby Dawson study

*** A special thank to Raffaele Tampolli for his skills and encouragement to achieve high quality standards. Raffaele has made all necessary mechanical parts.

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