TiSapph

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This document is outlining the points of consideration regarding the use/purchase of a TiSapph in ACME Gen. 2 in order to perform detection using the $|I\rangle$ state.

1 Why?

- The new laser will allow us to detect at a different wavelength to that which we are using for STIRAP, eliminating problems of scatter.
- The fluorescence frequency (512 nm) permits use of a PMT with higher quantum efficiency (25% vs 10%).
- The transition strength seems to be significantly greater than for $|H\rangle \to |C\rangle$, so we will hopefully be able to power broaden more.

2 Summary

We have two options for a laser — the M-squared laser, or the Matisse, below I summarise the relevant quantities/options for both. See below for more details.

Item	**M-squared**	**Matisse**
Cost	100k-200k	$\leq$30k
Wavelength	670-710/700-800	?
Power	0.7 W-2.5 W	2 W
Linewidth	20 kHz free-running, 100 Hz locked	?
Availability/Lead Time	?	$\sim$3 weeks, pending Marcus's decision
Delivery	Fiber/free-space	
Tuning	Serrodyne+ULE/Fiber switch/Galvo/Beat-note	
Pump	New Sprout or Jerry's Verdi	

Table 1: Summary of important options to consider when choosing the laser.

3 Cost

The cost of the M-squared laser is according to the quotes we have, which specify the cost to be \$100k using the 8 W Verdi which we supply, \$155k using a 12 W Sprout included, \$170k using a 15 W Sprout included. The optional extra of a scanning reference cavity adds an extra \$10k. Lead time 6 weeks typical.

The cost of the Matisse is estimated to be no more than around \$30k, based on the assumption that we have to buy a new mirror set (?) and on the labour involved.

4 Wavelength

The M-squared wavelengths are for two different models. The former covers the $X - C$ and $H - I$ transitions, the latter covers $H - I$ and $I - Q$ (?).

5 Power

For the M-squared laser we have been quoted that the power at 703 nm (690 nm) will be 0.7 W (0.5 W) with the Verdi, 1.3 W (1.0 W) with a 12 W Sprout, 2.0 W (1.5 W) with a 15 W Sprout. There is also an even higher power version which we are getting details for.

The power for the Matisse is an estimate based on the fact that with an 18 W pump it was able to put out 6 W at 780 nm. We should also bear in mind that we would need a new pump to get that kind of power.

6 Linewidth

This is unknown for the Matisse.

The matter seems slightly confused for the M-squared. Cris said that the free-running linewidth of the laser is 20 kHz, yet Kang-Kuen says that it is 250 kHz, with it being narrowed to 50 kHz with the scanning cavity option. Either way these values are not specified for a characteristic timescale. The laser is expected to drift by VALUE MHz/day when free-running and VALUE MHz/day when using the scanning cavity. We have been assured by M-squared that it is possible to lock the laser directly to a ULE cavity, which should be able to (assuming no significant high frequency noise etc.) reduce the linewidth down to ~ 100 Hz.

7 Delivery

We have two options free-space or fiber. For the former we essentially only have to worry about logistics, and of course have greater power available. For fiber delivery there are two things to bear in mind to ensure that no damage occurs — inherent damage to the fiber and damage at the coupling point. I have a quote from NKT photonics that specs the laser power up to 1 W, with either SMA905 or FC/APC connectorisation. This is with a 10 m long photonic crystal fiber. I have enquired if they can go higher in power, M-squared say they have used the same fibers with 2-3 W and SMA connectors. I also have a quote from Schafter-Kirchoff for a 7 m photonic crystal fiber which can take 1 W of power. They say that the length is limited to 7 m by Brillouin scattering.

8 Tuning

There are a few options here. First we have to choose to shift the frequency at the laser, or with an external device.

Let's consider the latter — we have to use either an AOM or an EOM (serrodyne). An EOM is not possible due to power limitations. Using AOMs is possible, but we can't tune very far, and we have to either lose a lot of power dividing between AOM breadboards, or switch between them. We can perform this switching either with a fiber optic switch or a galvo-driven mirror. I have a quote for a fiber switch from Leoni for a 1x4 switch that can take 1 W of power. Switching times are typically ~ 1 ms. I also have a quote from a company BBN that also specs 1 W of power. Lifetime is 10^8 cycles which is 3 years running 24/7 at 1 Hz. If we use a galvo-driven mirror you can, according to my estimates from the specs from Cambridge Technology and Scanlab, change your beam angle by 90 degrees in around 2 ms with ¡5 µrad repeatability. I can't see specs on the lifetime.

If instead we want to scan via the laser piezo, we should consider the specs for these. The slow has a 50 Hz bandwidth with a tuning range of ± 15 GHz and the fast has a bandwidth of 100 kHz for a ± 40 MHz tuning range. We then have two options: we could lock the laser directly to the ULE cavity, through a fiber EOM, and then shift our error signal around via serrodyne modulation, or, we could lock a separate 703 nm diode laser to the ULE cavity and then perform a beat note lock. The serrodyne option may be complicated by the presence of additional peaks in the frequency spectrum of the light going to the cavity. In either case we probably want to 'sweep' the frequency shift. It would be nice to do some preliminary tests of this, but may be difficult without the TiSapph itself. Perhaps we could try with two diode lasers?

If we want to use the ULE cavity as a reference we should take care to the separate the light. I have found it difficult to find a suitable dichroic for the job, so we will likely need a custom one, and even then it might be difficult to combine/separate two such close wavelengths (note we could combine on a cube and lose half our power, and throw away half our PDH signals at 690 nm and 703 nm by using absorption filters which are a little easier/cheaper). We also need to consider the ULE cavity properties at the new wavelength. The transmission at 690 nm is spec'd at 0.009305%. Using this value gives an estimated finesse of 34,000. The transmission value at 703 nm is 0.012622%, which corresponds to a finesse of 25,000, so everything should be fine there.