Broadband optical delay with large dynamic range

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The use of atomic media to produce optical delay has predominantly exploited the steep dispersion associated with electromagnetically induced transparency (EIT) [1]. While this can lead to very low group velocities it has a severe bandwidth limitation owing to the narrow spectral range over which the transparency and steep dispersion occur, making delays longer than the pulse width difficult to obtain.

An attractive approach to realising a wide-bandwidth delay line utilises the intrinsic positive dispersion and high transmission between two absorption lines in an atomic vapour [2]. We have explored the delay and transmission properties of optical pulses tuned between the ^{85}Rb (F=2) and ^{87}Rb (F=1) components of the Rb D2 line, separated by about 2.5 GHz [3]. The observed optical delays for pulses at the frequency of peak transmission are shown in Fig 1a) for temperatures between 105°C and 135°C. A fractional delay (delay relative to pulse width) of 4.3 was observed for a transmission of 9% with good pulse shape preservation. The fractional delay is limited in these experiments by the pulse duration we are able to generate.

While temperature tuning provides coarse but slow tuning of the delay, we have been able to demonstrate rapid control using hyperfine optical pumping. Because the pulses are tuned between absorption resonances from different isotopes, an optical pumping laser tuned to the (F=1) or (F=2) ^{87}Rb component of the D1 line respectively reduces or increases the population of ^{87}Rb (F=1) ground state atoms interacting with the signal pulse, and hence the dispersion. In this manner, the delay at 110°C was reduced by approximately 17.5% or increased by 25% of the unmodified delay (Fig 1b).

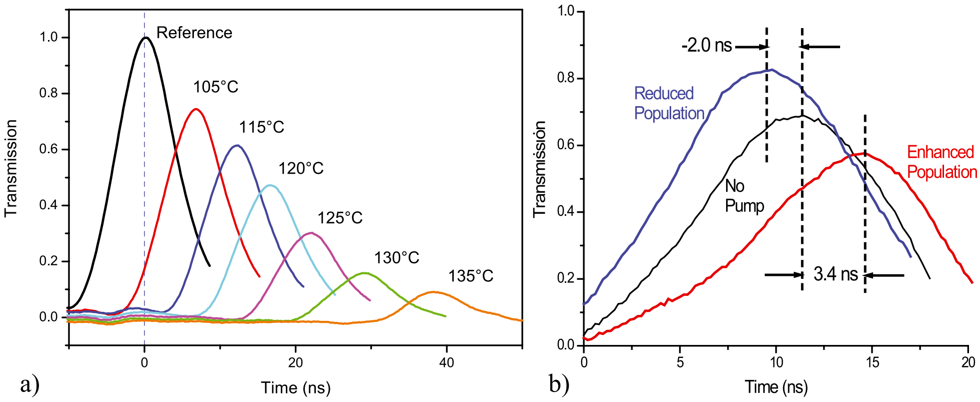

Figure 1: a) Delayed pulses with increasing temperature. b) Reduced and increased delay by optical pumping that reduces or enhances the population of the ^{87}Rb (F=1) ground state.

References

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