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INTRODUCTION

The Raman effect couples light to the electronic ground state of matter. This means that it is possible to utilize the long-lived coherence of the material excitation to control, measure and store optical radiation. This, in turn, enables a number of novel applications, including the generation of broadband light, the distribution of quantum entanglement and the storage and retrieval of quantum light for long-distance communications. We describe three applications of Raman scattering to technologies related to the above goals, using a variety of material excitations: molecular vibrations, bulk phonons in a crystalline solid, and atomic spin waves.

COHERENCE AMPLIFICATION FOR MOLECULAR MODULATION

A key challenge in coherent preparation of matter is to generate particular quantum electronic and vibrational excitations with a well defined phase with respect to ultrashort probe radiation. Typically, in time-resolved spectroscopic experiments for example, this problem is solved by using a pump-probe geometry with both pulses derived from the same source [1]. Material coherence is generated by nonlinear action of the pump, with parameters selected to maximize desired nonlinear effects. Improved excitation by increasing the pump energy may be unattainable due to deleterious competing nonlinear effects such as field ionization, for example.

It is possible, however, to prepare high-coherence molecular dynamics that are phase- stable with respect to ultrashort pulses without these drawbacks, using parametric Raman amplification of an initial single, or few phonon, excitation. We experimentally demonstrate an example of this scheme using a phase-independent, nanosecond-duration pump pulse to prepare a rotational coherence in molecular hydrogen. This rotational coherence is made phase-stable with respect to a separate source of ultrashort pulses by seeding. The coherence is used to generate spectral broadening of femtosecond probe radiation by molecular phase modulation.

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ENTANGLEMENT GENERATION BY MEANS OF PHONON MEASUREMENT

Recent advancement in synthetic fabrication techniques for diamond has resulted in increased industrial and scientific application. A source of diamond's uncommon electronic and thermal properties is its unique lattice and corresponding phonon features, including a long lifetime for a bulk material excitation. The low thermal population, lifetme and high Raman cross section suggest that it may be possible to generate entanglement between two rooms temperature diamond samples using recently developed methods based on measurement. The ability to effect appropriate optical measurements, however, has not yet been demonstrated. Recently, we developed a new spectral technique to read out single material excitations and to characterize phonon decay. The latter technique, Transient Coherent Ultrafast Phonon Spectroscopy (TCUPS).[2] TCUPS is a convenient, spectral method for measuring phonon dephasing and population lifetimes, and is a precursor to conditional state preparation for the diamond phonons.

STORING QUANTUM LIGHT

Quantum memories, capable of controllably storing and releasing a photon, are a crucial component for quantum computers and quantum communications. To date, quantum memories have operated with bandwidths that limit data rates to megahertz. Employing a protocol that makes use of far off-resonant Raman scattering enables this bandwidth to be increased dramatically, and thus to bring quantum memories closer to standard telecommunications bandwidths.[3] Using this approach, we have recently demonstrated the coherent storage and retrieval of sub-nanosecond low-intensity light pulses with spectral bandwidths exceeding 1GHz in warm caesium vapour.[4] The novel memory interaction takes place through a far off-resonant two-photon transition between two hyperfine states of the electronic ground state of the atoms in which the memory bandwidth is dynamically generated by a strong control field. This should allow data rates more than 100 times greater than those of existing quantum memories.

REFERENCES

1. P. J. Bustard, B. J. Sussman and I. A. Walmsley, Ultrafast pulse broadening by phase-stable Molecular Phase Modulation", submitted to Phys. Rev. (2009)
2. F. C. Waldermann, B. J. Sussman, J. Nunn, V. O. Lorenz, K. C. Lee, K. Surmacz, K. H. Lee, D. Jaksch, I. A. Walmsley, P. Spizziri, P. Olivero, and S. Prawer, "Measuring phonon dephasing with ultrafast pulses using Raman spectral interference", Phys. Rev. B, 78, 155201 (2008)
3. J. Nunn, I. Walmsley, M. G. Raymer, K. Surmacz, F. Waldermann, Z. Wang, and D. Jaksch, "Mapping broadband single-photon wavepackets into an atomic memory", Phys. Rev. A., 75, 011401(R) (2007)
4. K. F. Reim, J. Nunn , V. O. Lorenz , B. J. Sussman , K. C. Lee , N. K. Langford , D. Jaksch and I. A. Walmsley, "Towards high-speed optical quantum memories", Nat. Phot. (2010)