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Sound dispersion and damping in various forms of silica

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The properties of sound in silica glasses exhibit a complex dependence on the sound frequency ν and the glass temperature T. In spite of its considerable fundamental and practical interest, the understanding of sound dispersion and damping in silica based glasses has remained fragmentary so far. Models that seem successful in describing one region of the (ν,T) domain for one type of glass often fail elsewhere. We address this question by reviewing the available data and complementing them with new Brillouin scattering measurements in various forms of silica glasses and quartz. In particular, we measured with various light scattering probes permanently densified silica glass of density ρ=2.6 g/cm^3. This emphasized that densified silica is in many ways quite different from usual silica glass.

Analyzing the available information, we identify a damping contribution due to structural relaxation and a separate one due to anharmonic interactions between collective modes. Our observations also point to a smooth change of structure of vitreous silica with T, in line with recent molecular dynamics simulation results. They add to the understanding of the anomalous elastic and dilatation behaviours observed under applied pressure, thereby clarifying the origin of the unusual properties of tetrahedral glasses under pressure and in function of temperature.

In addition, performing Brillouin scattering with x-rays, we observe the end of the acoustic regime of densified silica at ν around 2 THz. Beyond, sound ceases to exist as such, the acoustic motions hybridizing with structural modes.

In summary, while many studies until now concentrated on the ultrasonic regime of normal silica, emphasizing structural relaxation damping, our studies of densified silica clearly reveal the importance of anharmonic damping in more compacted structures, and the crucial role of mode hybridization at the highest frequencies.