Theory of vibrational anomalies in glasses

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The experimentally measured vibrational spectrum of glasses strongly deviates from that expected from Debye's elasticity theory: The density of states deviates from Debye's ω^2 law ("boson peak"), the sound velocity shows a negative dispersion in the boson-peak frequency regime and there is a strong increase in the sound attenuation near the boson-peak frequency.

A generalized elasticity theory is presented based on the model assumption that the shear modulus of the disordered medium fluctuates randomly in space. The fluctuations are assumed to be uncorrelated and have a certain distribution (Gaussian or otherwise). Using field-theoretical techniques mean field approximations are derived for vibrational spectrum of the disordered system. The theory based on a Gaussian distribution is the self-consistent Born approximation (SCBA), The one for non-Gaussian distributions is the coherent-potential approximation (CPA). Both mean-field theories appear as saddle-point approximations of effective replica field theories. The theory gives a satisfactory explanation of the vibrational anomalies in glasses. Excellent agreement of the SCBA theory with simulation data is achieved.