Fluctuations in dielectric losses in amorphous nanoscopic samples

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Introduction

Low temperature dielectric Two Level Systems (TLS) in amorphous solids have gained much attention in recent years due to their performance limiting effect in superconducting quantum bits and resonators for quantum computing. TLS are represented by atoms or groups of atoms tunneling between two configuration states. It has been found that they decrease the coherence of qubits due to microwave absorption. The control of the two level system response is an important task for making quantum bits using Josephson junction qubits. Under certain conditions of low temperature and a small sample volume, the system response is determined by only one two level system most close to resonance. At this point it is possible to coherently modify its quantum state by applying external ac and/or bias fields. The target of the present task is to attain the quantitative data for reaching the regime of single TLS response.

Methods

MATLAB R2015a was used to develop software for the generation of TLS's parameters in the dielectric samples. The parameters were created using a random number generator for the proper number of TLS *i*. The study includes the calculation of loss tangent for different realizations of TLSs, analysis of the fluctuations depending on the system volume, temperature, TLS's dipole moment, and interaction constants as shown in the equation below.

$$\tan(\delta) = \frac{4\pi}{\text{Ú}V}\tanh\left(\frac{h\omega}{2\kappa_B T}\right)\sum_i \frac{p_{iz}^2}{2T_{1i}\left(\delta_i^2 + \frac{1}{4T_{1i}^2}\right)}$$

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Results

The results show that systems with greater TLS N the behavior of the TLS average close to resonance.

Fig. 1

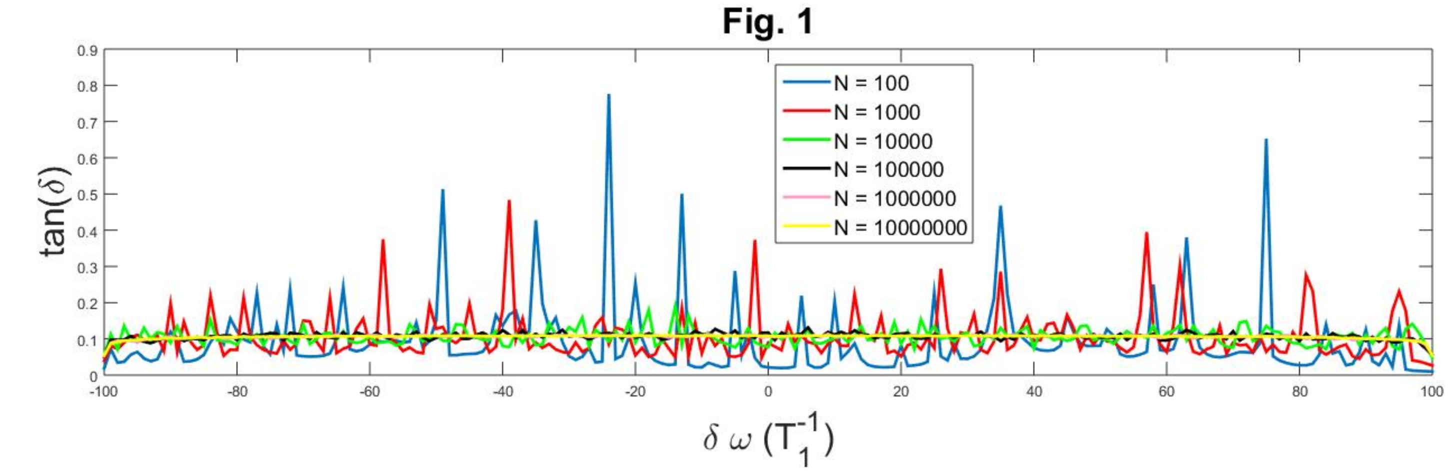


Fig. 1 shows the reaction of TLS at varying amounts of TLS N. It depicts how at lower amounts of TLS there is greater variance in the behavior and at greater amounts of TLS, the behavior of the TLS converges close to resonance.

Fig. 2

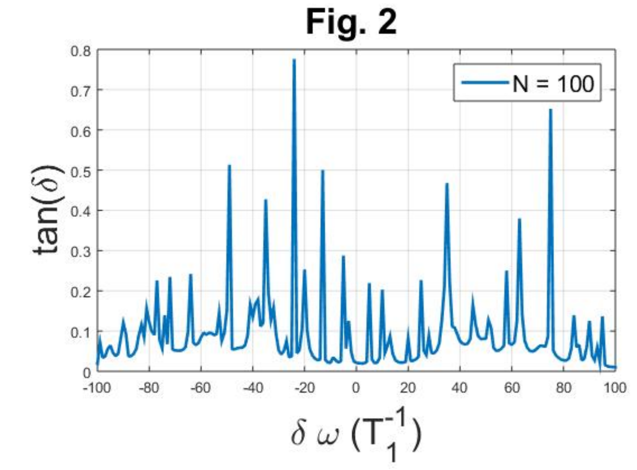


Fig. 3

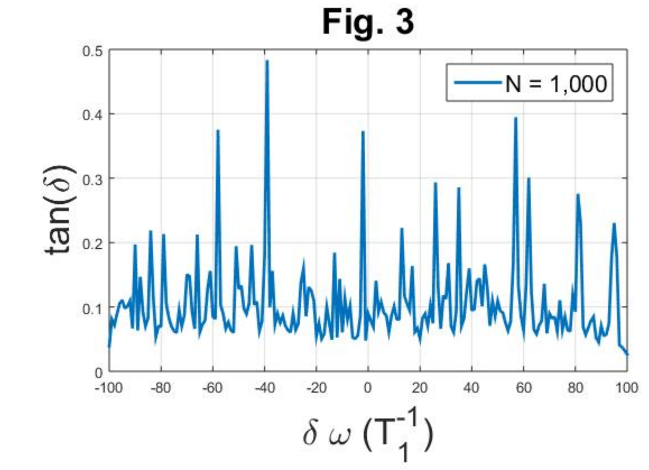


Fig. 4

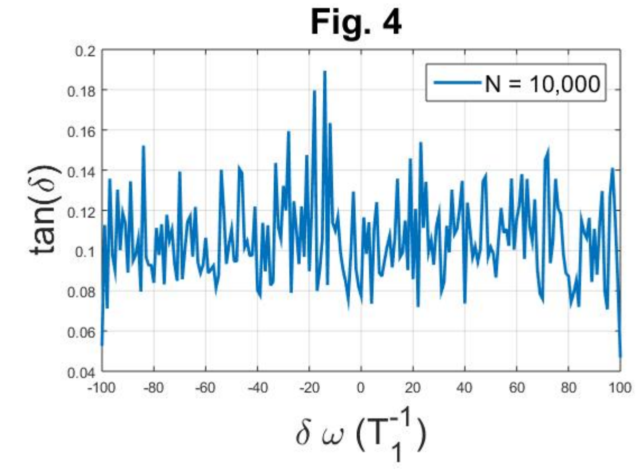


Fig. 5

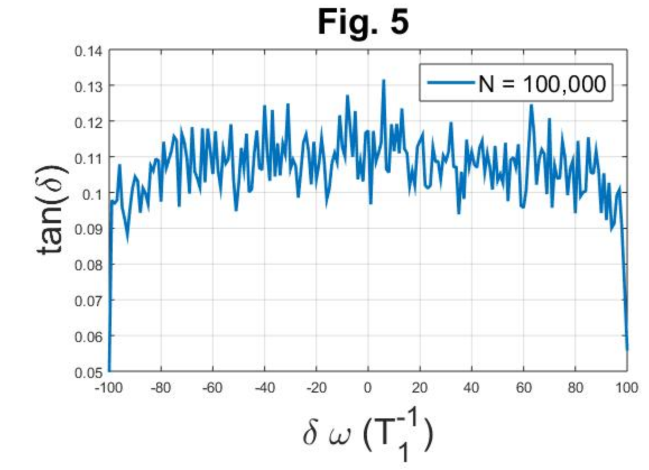


Fig. 6

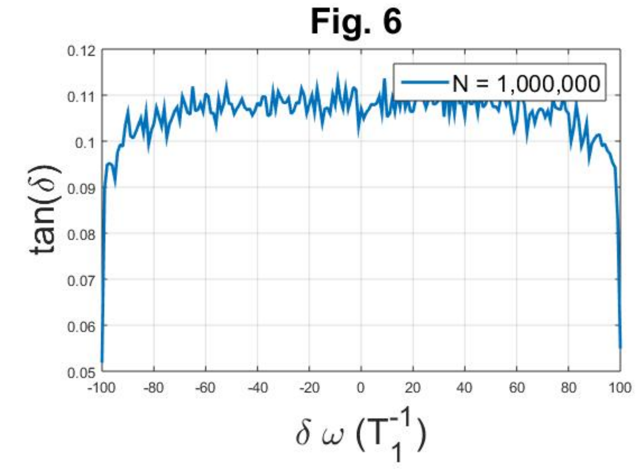
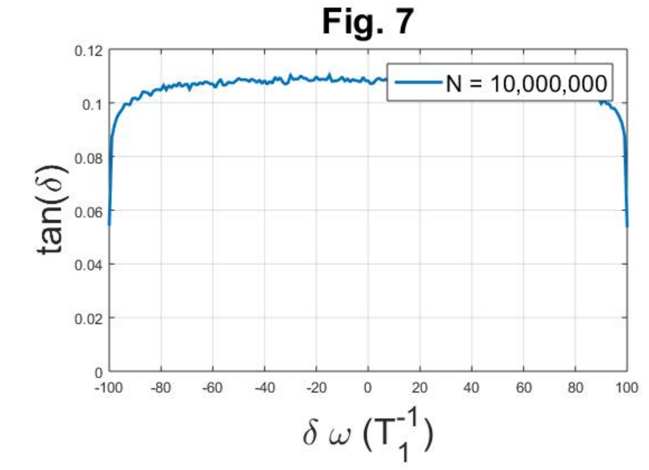


Fig. 7



Conclusion

The data depicts that when observing few amounts of TLS, around 100 and below, the individual responses are significant when predicting their behavior. It also demonstrates that with large amounts of TLS, roughly around 100,000 and above, the individual responses are not as significant when predicting their behavior. This is due to the fact that they begin to average out at approximately the resonance of the system. This is significant when trying to predict the effects of TLS when working with superconducting qubits.

Future Work

These results can be applied in other areas of interest including the analysis of the non-linear dielectric losses, flicker noise, and the investigation of the telegraph noise effect on the non-linear absorption of microwaves

Sources

Burin, Alexander L., Moe S. Khalil, and Kevin D. Osborn. "Universal Dielectric Loss in Glass from Simultaneous Bias and Microwave Fields." *Phys. Rev. Lett. Physical Review Letters* 110.15 (2013): n. pag. Web.

Acknowledgements

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