We examine the feasibility of enhancing the fundamental radiative interactions between distant atoms. We present general arguments for producing enhancement. In particular, we show how giant dipole-dipole interaction can be produced by considering dipoles placed close to micron sized silica spheres. The giant interaction arises as the whispering gallery modes can resonantly couple the dipoles.

Introduction

It is well known from the early days of quantum electrodynamics\(^1\) that the exchange of a photon between two atoms leads to the radiative coupling between the atoms. It is also known that the strength of such a radiative coupling is significant only if the distance between the two atoms is much smaller than the wavelength of the transition involved in the coupling. In this work we demonstrate the possibility of remarkably large radiative coupling between atoms which could be separated by distances much larger than the wavelength. In what follows, we concentrate on one specific type of the radiative coupling, viz., the retarded dipole-dipole interaction. We begin by recalling how the radiative coupling arises.

Consider, for example, two atoms \(A\) and \(B\) located at positions \(\vec{r}_A\) and \(\vec{r}_B\), respectively. Let at time \(t = 0\) the atom \(A\) be in the excited state \(|e_A\rangle\), and the atom \(B\) in the ground state \(|g_B\rangle\). Such a selective excitation can be achieved by using an optical fiber tip. We assume an allowed dipole transition between \(|e_A\rangle\) and \(|g_A\rangle\). Clearly we can have a transfer of excitation from the atom \(A\) to \(B\), i.e., the initial state of the system has changed from \(|e_A, g_B\rangle\) to \(|g_A, e_B\rangle\). The electromagnetic field is in vacuum state at \(t = 0\) and is again in vacuum state after the transfer of excitation is completed. This process \(|e_A, g_B\rangle\) to \(|g_A, e_B\rangle\) is mediated by the vacuum of the electromagnetic field. This transfer process can also be described by an effective interaction, which depends only on the atomic degrees of freedom. Thus, the atoms \(A\) and \(B\) get coupled via the radiative interaction. The amplitude for such a process can be calculated in the framework of quantum electrodynamics using the second order perturbation theory. Let \(d_{\alpha\beta}\) be the dipole matrix element for the transition \(|e_\alpha\rangle \to |g_\alpha\rangle\). As shown in the appendix a quantum electrodynamic calculation shows that the effective