Wave Particle Duality

The problem with both the WPM and Einstein's model is that a single photon particle that has a localized trajectory through only one of the two slits in the double slit experiment, even if it has a vector field surrounding the particle that changes causally, will generally give different predictions than a photon wave going through both slits (as we will see later in Chapter 4, Bohm's theory is a case of a local particle trajectory theory, but is supplemented with a generally *non-local* guiding field). One can still conduct a double slit experiment even when the distance between the slits is many multiples of the wavelength. Hence, one would have to believe that a particle would go through only one of the two slits, but somehow still be guided by the fact that interference is required *as if* the particle went through both slits.

One is led to the wave-particle duality problem in order to come to terms with how it can be that an individual light particle, i.e., a single photon, can interfere at different locations and thereby appear to exist as an extended or non-local wave, but also somehow cause the ionization of an atom for which the entire energy $E = h\nu$ of the photon must be transferred to the position of the atom, which can be extremely localized. In fact, the atom may be physically (orders of magnitude) smaller than the wavelength of the light.

Issues associated with wave-particle duality were being considered by Einstein, Bohr, and others prior to the development of Schrödinger's equation and Born's rule. Although many relevant experiments were being carried out during these years, experiments at the individual particle level were not plentiful and the physics of such events could be hypothesized but not easily verified by experimental evidence. It does not appear to be a simple matter to develop quantum theory without sufficient experimental evidence. In 1924 a theory by Bohr, Kramers, and Slater (BKS) was put forward in which the electromagnetic field was treated as a wave and not as a particle. BKS were not able to develop a theory that would conserve energy on all individual scattering events and at the same time retain the property that the electromagnetic field acted as a wave. BKS allowed for individual quantum transitions to violate conservation of energy, but energy would still be conserved on average. The theory was opposed by Einstein, and experiments were conducted by Bothe and Geiger and independently by Compton and Simon in 1924-1925 that examined individual scattering events. It was found that energy and momentum *are* conserved on individual scattering events. BKS theory was thus found to be incorrect and this added insight into the issue of wave-particle duality. For the most part, from 1925 through to the present there appears to be agreement on this. The framework of how this occurs however has been a hotly debated question, which seems to have begun nearly immediately upon Schrödinger's discovery of his now famous equation of quantum mechanics.