Blueshift of an Electron in Amplitude Splitting Interference
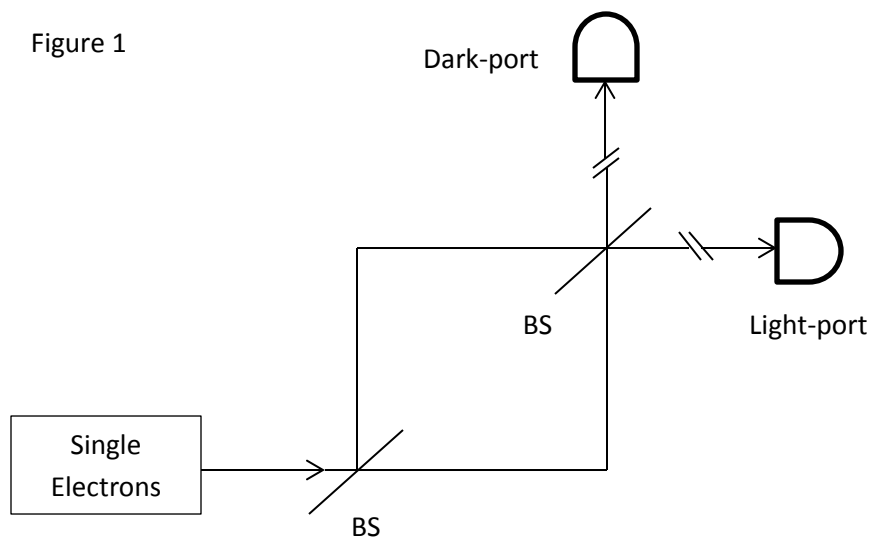
We consider a single electron amplitude splitting interference experiment with respect to the possibility of a blueshift in energy/momentum due to the changes in static electric potential.

This paper is a restatement of a previously published paper[1] with a simplified approach to analysing the theory and experimental proposal. The over-all presentation is a straightforward analysis of amplitude splitting interferometry with single electrons and a theoretical discussion of the possible blueshift in energy that the electron undergoes in this preparation.

We consider the preparation of a single electron interference effect which uses an electron beam splitting and recombination apparatus and two detectors. The ideal optical interferometer of this form is that which would be referred to as the Mack-Zehnder interferometer. In electronics this idealized form of amplitude splitting interferometry is the Marton interferometer. We assume a standard amplitude splitting interferometer for single electrons as is depicted in Figure 1. This illustration assumes the use of two beam splitters (BS) which would be appropriate for optics, but realistically in the case of electronics we would be using a different apparatus.

Figure 1

The interferometer has two outputs which will have light-port/dark-port statistics when the interference is at a central maxima due to a zero phase difference in the two paths. This configuration of the interferometer is the only consideration that is analysed in the current document. The mathematical analysis that we will provide is a treatment of the energy of electric potential for each electron due to the static fields of all other electrons in the beam. In electron interferometry this potential is usually not considered because it is negligible. The typical assumption in quantum mechanics is that the interaction of successive electrons within the beam is of insufficient strength to disturb the single electron states of the beam because the interaction strength is too weak to affect the states of the electron. This is a necessary assumption in single electron interferometry because the

beam would decohere otherwise. But what is the strength of this potential energy and how does it change due to the electrons transmission through the interferometer?

When we analyse things in the rest frame of the electrons, the energy of electric potential for a single electron in a line distribution of electrons can be calculated by simply summing the energy of electric potential that this electron experiences due to the fields of rest of the electrons. We will assume a line of 2N+1 electrons in the beam and we evaluate the potential for the electron in the middle of the distribution. The potential energy experienced by each electron, V, is given as

$$V = \frac{e^2}{2\pi\epsilon_o x} \sum_{n=1}^{N} \frac{1}{n}$$

where x is the average distance between successive electrons in the beam. This expression has a divergent sum on the far right that results in a different value for differing values of N, so we tabulate the approximate value of the sum below for many values of N.

N	≈Sum
100	5.19
1,000	7.49
10,000	9.79
100,000	12.09
1,000,000	14.39

This dependence of $V(N)$ upon the choice of N forces us to assume a value of N for simplicity purposes. So we assume that there are 20,001 electrons in the beam (and we are evaluating the potential of the electron in the center of the beam) which would give us N=10,000 and Sum≈10. We also use an approximation of $e^2/2\pi\varepsilon_0 \approx 3\times10^{-9}$eV·m, which leads to the following expression for the energy of electric potential for each electron

$$V = \frac{3 \times 10^{-9}(eV \cdot m)}{x}$$

So by substitution of the average electron spacing, x, as being on the order of 3 centimeters (x=3×10^{-2}m) we arrive at our final approximation for the average potential energy per electron in the beam (due to the field of the other electrons in the beam) as

$$V \approx 10^{-7} eV$$

This is a roughly calculated statement of an approximate potential energy per electron as calculated in the rest frame of the electron, and only for the specific case where the electrons are spaced on average by 3cm in the beam, and only for the case where there are 20,001 total electrons in the beam. So let's assume this to be an indication of the *order of magnitude* of the potential energy of each electron in an electron beam.

The question is, what if we subject an electron beam to a beam splitting preparation as in Figure 1? This action which splits the beam must have the effect of "spreading out the electrons" in a manner that the average spacing, *x*, is now doubled (if we assume the beam splitter is a 50/50 beam splitter with two outputs of roughly half the intensity of the input beam). This action of spreading out the electrons must also have the effect of reducing the energy of electric potential to half the value. Because the beams are separated quickly we would assume that the reduction of potential is compensated by an equal increase in kinetic/vibrational energy of the electrons. This should be measurable as a blueshift in the spectrum of the electrons that exit a beam splitting apparatus. This may be a trivial effect, but what we really wish to question is whether there is a similar effect occurring when we have the full preparation of Figure 1 with recombination at another beam splitter and the interference measurement outcomes which would have all the electrons exiting a single light-port output. We would argue here that there are two possible interpretations of what happens with the beam of the light-port electrons in Figure 1:

Interpretation 1: The output of the light-port electron beam is identical in every way to the original beam that is emitted from the source. When the beam is split with the first beam splitter the two outgoing beams are blueshifted, but upon recombination at the second beam splitter the beams then recombine to redshift the electrons back to their original state.

Interpretation 2: The output of the light-port electron beam is blueshifted in a manner that does not comply with the conservation of energy. The energy of each electron is increased. When the beam is split with the first beam splitter the two outgoing beams are blueshifted, and when the beams are recombined at the second beam splitter we would assume that the two outputs of the second beam splitter are equal in intensity (which would imply that the blueshift is still valid). If there was no interference occurring (due to the marking of paths by some means) this would be the outcome, but because the interference occurs we must conclude that all the electrons exit one output in a beam with intensity identical to the emitted beam. Remember, the calculation of interference is a matter of quantum mechanical theory (adding before squaring instead of squaring before adding) and this calculation of interference is *mutually exclusive* to the calculation of energy of electric potential.

   Considering these two arguments, we have come to the conclusion that Interpretation 2 has merit. It is possible that the calculation of energy of electric potential and the calculation of interference are *mutually exclusive* calculations. When we subject a beam of electrons to the preparation of a beam splitter alone, we calculate the energy of electric potential based upon the output beams each having half the intensity (and double the average electron spacing, *x*) which implies a blueshift of the electron energy spectrum for all electrons. Similarly, if we were to start with two separate sources of electron beams (with equal intensity and identical state) and combine them at a beam splitter we would expect two outputs of the beam splitter that resemble the initial inputs in intensity so that the two beams are unshifted. So what if we take a single beam and subject it to a beam splitter (which should produce two blueshifted outputs) and then recombine the two outputs at a second beam splitter to produce two more outputs? Under almost all circumstances we would expect the outputs to be identical in intensity and energy to the two inputs (blueshifted once from the state of the originally emitted beam). Only in the unique circumstance where we have met all the conditions for interference (coherent beams) would we expect to see the outputs of the second beam splitter differ in intensity in the manner that one is a

dark-port and the other is a light-port, as in Figure 1. In this case do we anticipate that the output of the light-port (where all the electrons exit) should have a redshifted energy spectrum so that the total state of the beam includes the original blueshift and the second redshift (unshifted in total)? In order to anticipate one or the other outcome we must calculate the energy measurement based upon a more involved calculation of the final results which somehow combines the calculation of interference with the calculation of energy of electric potential, which doesn't make sense because the energy of electric potential calculation is based upon an interaction which is too weak in strength so it doesn't get included in the interference calculation. The only other way to anticipate the energy measurement outcomes is to assume that the output configuration simply determines the energy calculation in accordance with the law of conservation of energy. This would be insufficient reasoning because we wish to have our calculations based upon theoretical estimation from first principles rather than just matching our calculation to the known output configuration of interference. If this second means to anticipating the energy measurement is the only means to calculation, and it is correct, and it is so in accordance with interpretation 1 above, then we must conclude that quantum mechanics somehow simply conserves energy in all circumstances.

  If interpretation 2 is correct, then an obvious means to free energy/momentum production follows from this paper. We simply use a charged particle interference preparation (or a charged particle spin recombination preparation, etc.) to increase the energy of every particle which transmits through the interferometer. Either combining the interferometer with a feedback loop to subject each particle to many interferences or subjecting the particles to many interferometers in sequence should increase the energy/momentum of the particles in a desired fashion.

References:

1) Thomas Alexander Meyer, *Potential Energy Shift in Single Electron Spatial Interference*, (2013). This paper is available at http://vixra.org/abs/1312.0037