Summary, January 2020

1 Summary

This summary describes my perception of the issues which must be solved in order to proceed with a moonbounce experiment.

For step 1 of the experiment we wish to demonstrate interference whose visibility is modulated by the uncertainty principle. To do this we seek:

1. an experimental setup using radio or radar transmission;
2. a configuration such that photons with different paths can be switched between being distinguishable and indistinguishable by varying the observation bandwidth or integration time;
3. we need the means to observe interference effects between indistinguishable photons that disappear when the photons become distinguishable.

Dave asked last week what our direction is. I've had several concerns about the feasibility of this experiment, and have been working on these– I'm no more of an expert than anyone else in this group, but I've been hacking away. Here have been my main questions:

1. Does the time-energy uncertainty principle actually rate on the same level as the position-momentum one? I.e., can it actually be used to influence experimental results?
2. What do the diffraction fringes from the Moon look like, classically? And, do we expect to be able to produce spatial fringes from any reasonable configuration of transmitter/receiver?
3. Can a radio telescope or array detect spatial fringes?
4. Is it easier to detect the quantum effect of photon bunching than spatial fringes?
5. Are we able to get the bandwidth and time resolutions necessary to switch back and forth between distinguishable and indistinguishable photons?

Some brief arguments are below:

Re (1), some knowledgeable authors say they wouldn't trust experiments that propose to manipulate it; there are several different derivations of the principle; there's no lab experiment been done that just uses the information in the signal to achieve fringe/no-fringe– all experiments alter a physical setup. But a couple of papers suggest that the principle can be used to determine the distinguishability photons received at a detector.

Re (2), the reflected signal from a portion of the Moon should look something like a deformed Airy function, with fringes, but it's complicated by the fact that it's not a disk; it's really hard to determine what it will look like– but creating the solution via analytics and ray tracing should be preceded by answering the next question:

Re (3), a single dish collects power at its focal point and doesn't image; two dishes placed at distances from each other might register anti-correlation if one is on a minimum and the other on a maximum, but how to place them; a phased array (correlator) gets an image, but it is assembled globally and has artifacts, will not likely resolve fringes; if we use two beam former images of different locations, Gerry thought that correlation between the readouts would indicate interference– but it might also be explained classically;

Re (4), photon bunching seems a likely phenomenon to look for. It does an end run around the difficulties with detecting fringes, but it's a little complicated.

Re (5), Gerry and I found a paper that had arguments similar to ours, and we used these to determine what the signal would be to have essentially a single photon at a time in the system, and what bandwidth would be necessary to skip back and forth between distinguishable and not; that question seems answered enough to pursue the other ones.

Finally, there are other questions we have been pursuing, tailored to the difficulties that arise from mirrors. For instance, adjusting the configuration so that we can use two frequencies so as to get a single frequency that could come from either of two places on the Moon.

2 Observing Interference with Radio

Historically Doyle and Carico considered an astronomical scale double slit experiment producing interference fringes with spatial extent, but it might be easier to look for 2nd order correlations due to quantum effects that are present in the time-wise readout from a photon field.

2.1 Complications due to Mirror's (Moon's) Shape

The actual experiment does not use two mirrors (slits), but rather a large, continuous mirror which may be thought of as consisting of billions of tiny reflectors arranged continuously.

Classically, this configuration will be expected to produce a diffraction pattern with interference fringes, due to differing photon path lengths. Small surface perturbations will be expected to average out, but there should be a larger pattern associated with the spherical shape of the Moon itself. I don't know how to calculate the expected diffraction pattern except for ray tracing.

There's also an issue of coherence length. Typically one would expect a spatially distributed speckle pattern to be observable at a receiving antenna, similar to the speckle patterns observed from lasers. I don't know how to resolve the expected coherency size of the speckles from a radio transmitter.

Any signal also undergoes a time-wise convolution with the Moon's topography, introducing autocorrelation into the received signal.

2.2 Complications with Radio

A single radio dish collects all power at the focal point and does not resolve images. It is impossible to observe spatial interference fringes with a single radio dish.

With two radio dishes, one could hope to place them at a distance such that one dish was at a maximum of any interference patter, and the other at a minimum. Interference would rely on one dishes signal dropping relative to the other when photon paths are indistinguishable.

Historically, Doyle and Carico focused on spatial interference patterns. There are two methods one could use to detect spatial interference:

1. use an array of dishes with a phased array or correlator approach to try to get a spatially resolved image with fringes. This is probably impossible to do, due to the fact that images are built using globally convergent Fourier series, and will contain artifacts;
2. use two beam formers to get high quality signal from portions of the lunar surface, and compare these for autocorrelation;