Messaging Extra-Terrestrial Intelligence (METI) – A Local Search

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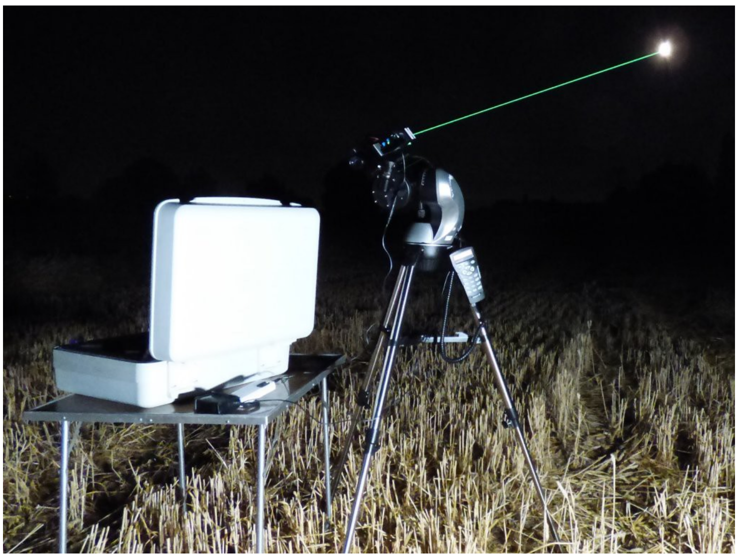
Abstract: This paper examines the feasibility of an amateur approach to METI using cheaply available lasers and optics. We suggest a novel variation in the search methodology, concentrating on contacting any interstellar extraterrestrial probes that may be present in the solar system. Specifically, the Lunar poles and Lagrange points L4 and L5. It is assumed that such a probe incorporates advanced artificial intelligence (AI) at or beyond human level. Additionally, that it is able to communicate in all major languages and common communications protocols. The paper is written in non technical language with sufficient information to act as a "how to" source for technically knowledgeable people.

Other more technical versions of this are available.

Dirk Bruere



The Apparatus

Left to right:
- Dirk Bruere
- Sara MacKenzie
- Dr Amon Twyman
- Fiona MacKenzie (photography)

Historical Introduction

On 16 November 1974 The radio telescope at Arecibo sent a brief message to the M13 star cluster some 25,000 light years distant. It comprised some 210 bytes of data sent at a bitrate of 10 bits per second and a power of around one megawatt. The (colored) pictorial representation is shown here. It is probably the best known attempt at contacting extraterrestrial intelligence (ETI), even though it was not serious, was not the first and by no means the last.

The first was a Morse code message sent from the USSR to Venus in 1962 which was even shorter. It is known in Russian as the Radio Message "MIR, LENIN, SSSR".

Latterly, in 2016 on 10 October 2016, at 20:00 UTC the Cebreros (DSA2) deep-space tracking station of the European Space Agency sent a radio signal towards Polaris, the Pole Star, which is approximately 434 light years from Earth. The message consisted of a single 27,653,733 byte, 866 second transmission. Again, it was not a serious contact attempt, and was rather more a work of performance art by Paul Quast.

A few, more serious, attempts have been made in the intervening years[i], targeted at more plausible planetary systems but none for any sustained period of time.

So, enter METI[ii] or "Messaging Extra-Terrestrial Intelligence" who aim to start a serious and comprehensive program of signaling various star systems some time in 2018 if they can raise the estimated $1million per year needed to run the program. For once, judging by their website, they intend to do it properly with a great deal of effort going into the communications protocols of the messages themselves.

Laser Communication

And that is where we were until June 2017 and a paper[iii] written by Michael Hippke examining the possible role of using the gravitational lensing effect of our sun to amplify laser signals across interstellar distances. The surprising conclusion was that using optical wavelength lasers and mirrors of only one meter diameter, data could potentially be transferred at megabit per second rates using around one Watt of power over 4 light years. This, to put it mildly, is spectacular especially since the receiving technology is potentially within our ability, assuming we could locate a telescope some 600 astronomical units (AU) from the sun. Unfortunately, our most distant spacecraft is Voyager 1 at about 140AU. He also showed in a previous paper that the data rate drops to bits per second per watt using a 39 meter receiving telescope and no lensing.

However, if we turn that around and assume that ETI have a superior technology to us and can implement suitable receivers, then to contact them we need only very modest laser transmitters. Ones that are well within the budget of hobbyists and amateur astronomers.

The advantage of using lasers is more apparent, especially for amateurs, when we consider beam divergence. Lasers can quite easily achieve divergences of less than one milli-radian (mrad) which corresponds to one meter per kilometer. To achieve that with microwaves at (say) 6GHz would necessitate a transmitter dish of approximately 65 meters diameter. A very expensive piece of radio astronomy kit. This also means that power levels can be significantly less than would be needed for radio communication.

Nevertheless, there are serious caveats. These mostly concern the location and type of transmitter. For example, to limit beam spread Hippke assumes a one meter diameter mirror and a beam spread of considerably less than a milliradian, so we are going to assume a rather larger receiver at the ETI end in order to minimize beam requirements at our end.

A much more serious problem is that the mirrors have to be aligned with each other. Specifically, the transmitter should be relatively stationary in space, and not on a rotating planet which is in turn circling its sun. If the latter is the case, the receiver will probably only align at fixed intervals lasting no more than a few tens of milliseconds unless very precise aiming technology is used.

However, there is a more interesting search regime far better suited to low budget than attempting interstellar communications.

Exploratory Scenario

This is a METI search that will be primarily focused on contact with self replicating Von Neumann (VN) style interstellar probes[iv]. There are strong arguments that over a timescale of the order of thousands to a few million years these are the best way of exploring the galaxy by any intelligent technology oriented species. Once one of these devices arrives in a solar system it sets about creating sufficient infrastructure to both report back to its home system (as well as possible siblings) and create a replica of itself for onward launch to multiple other stars. Reasonably conservative capabilities are as follows:

- They are very likely to outlive the species that sent them
- They would almost certainly embody an artificial intelligence (AI) at or beyond Human level capability
- They would be self repairing and possibly have a lifetime in the tens of millions of years, barring accidents
- They could exist around just about every star in the galaxy within ten million years

Using the kind of technology we might reasonably expect to appear sometime in the next century or two, such as placing observatories at the gravitational focal point of our sun, some 600AU out, we could view details on nearby extra-solar planets. And anyone out there could do the same to us. As a consequence, Earth has likely been an interesting place to view for the past 300 million years or so with its oxygen atmosphere and vegetation. And vastly more interesting in the past 10,000 years since rectangular shapes started appearing in the form of cities and fields. Rectangles generally do not occur naturally. Then in the past 300 years the atmosphere started to show signs of industrial pollution, followed 200 years later by radio and TV signals, intense radar pulses and the unmistakable sign of nuclear bombs whose output peaked at around 1% of the total output power of our sun.

If ETI exists, or has existed, within a few thousand light years there is a strong possibility that their probes are already here, and have been for a considerable length of time.

This leads to a number of massively simplifying assumptions, again quite reasonable given the scenario above. These are:

- Since we are now searching within our solar system power levels can be vastly reduced.
- Message transit times, in both directions, are no more than a few hours maximum and possible only seconds.
- Any intelligent VN probe that has been examining Earth will have been monitoring our technological development and radio/TV output. As a consequence it will almost certainly understand all the major languages both written and spoken as well as our communications protocols.

We need to consider beaming our messages at likely locations within our own solar systems. For example, where would we place intelligent probes to wait out the ages and watch developments on Earth? Among strong possibilities are the Lunar poles, Lunar caverns which we now know exist[v] and the Lagrange points[vi] associated with Earth's orbit, particularly L4 and L5, where position can be held with little expenditure of energy. We intend to beam laser messages to these points as part of the Zero State program.

But what messages? People have given much thought to creating a communications system that can be decoded by ETI, as mentioned above with METI. However, we contend that the answer is simple – we use English, and code in simple ASCII.

What has been lacking from Earth is a specific invitation to communicate or visit. It is this that forms the core of our project.

How Far Can We Be Seen?

Suppose we want to do the crudest communication system possible – a laser doing Morse Code. To the unaided Human eye, how far away could we see the beam? This depends on several factors:

- Beam Divergence
- Beam power
- Wavelength
- Eye sensitivity

Taking these in turn...

The power we will assume to be one Watt since this level of power is quite economical, and the wavelength to be either 532nm or 520nm, the latter being a pure diode output, not frequency doubled.

It is also the approximate wavelength where the eye peaks in sensitivity, and in our project is partly chosen for this reason. We could have gone for high power infrared in the tens of watts, or maybe towards the blue/violent end of the spectrum. However, green is not only easier and safer to work with, being highly visible, but is quite photogenic. From a safety point of view you seriously do not want an invisible beam of blinding intensity sweeping about. That would also be more difficult to aim and focus.

So we have an intensity of approximately one Watt per square meter at a distance of one kilometer, with the intensity dropping off as the square of the distance. At 2 km we have 0.25W per square meter, and so on.

Finally, what is the maximum sensitivity of the dark adapted Human eye? It appears to be about 100 photons per second[vii], but for the sake of argument we shall assume a level ten times lower, or 1000 photons per second in a dark adapted eye whose aperture is 100 square millimeters. That gives us a minimum intensity requirement of 10^7 photons per square meter per second. With each green photon carrying an energy of approximately 3.5e-19 Joules we get a required power density of 3.5e-12 Watts.

So, how far can our 1W green laser with a divergence of 1 mRad travel before we hit that value? The answer is a little over 500,000km – further than the Earth-Moon separation. By the time the beam gets there it will be illuminating a circle some 500km in diameter.

If we are looking back from the Moon via a modest telescope such a beam would appear as a bright flickering point of monochromatic light. Even a 100mm diameter telescope would improve visibility by more than 100 times.

If we wish to improve the numbers there are certain things we can do. If we increase the power, it scales linearly in intensity at a given distance. If we increase the collimation to (say) 0.5mRad the intensity quadruples, but the illuminated area decreases 75% as the spot size halves.

Proof of Principle Equipment – Stage 1

The setup described below is an absolute minimum and has been put together simply to illustrate how easy it can be, and how cheap.

WARNING! - The lasers described should be treated like a loaded firearms with the safety off. Anyone around it should have eye protection goggles when it is operating or being worked on. If it sweeps across your eyes it will cause instant permanent blindness. It can also start fires. These are Class 4[viii]. You should also assume they will cause eye damage out to 1km if the beam is not expanded.

The basic equipment list is relatively straightforward – example sources are UK but may be obtained cheaply elsewhere:

- A computer with a USB interface
- A terminal emulator program such as Realterm[ix] or similar
- A USB to TTL converter cable[x]
- A battery based stabilized power supply for the laser module
- High power laser module 1 Watt or greater[xi]
- A telescopic rifle sight (scope)
- A GOTO telescope
- Various Weaver rail fittings and adapters
- A low power sighting laser
- Laser safety goggles

Less straightforward is any metalwork or optical interfacing of the laser module, however, the use of a scope with integral Weaver rails simplifies things considerably. The scope needs an attachment to the GOTO telescope, and the rest of the equipment attaches to the scope.

The next problem is that of holding the telescopic sight on target, which is where a motorized equatorial mount, or GOTO mount is required. Both will compensate for the rotation of the Earth and hold on a previously acquired target with accuracy much better than the assumed mrad (for scale, the diameter of the full moon in the sky is about 9 mrad) A GOTO telescope is fully computerized and will automatically move to designated targets either by name or celestial coordinates.

The first step is to securely attach the laser module co-axially to the telescopic sight so that you can see through the scope where the beam strikes. To do this you need a deserted area where you can aim the beam at a target some 100 metres distant and adjust optics and mechanical attachment so that the beam is aligned and parallel to the cross-hairs.

At this point you can examine the beam quality. With modules such as the above it will not be a round spot. More likely it will be an image of the emission diode structure. Not ideal, but good enough for now.

The pictures below show the scope, sighting laser and Class 4 laser complete with a DIN rail that is used to attach all this to the telescope. In this instance it is mounted on a camera tripod for alignment work.

Illustration 2: Right Side of the Lasers and Optics

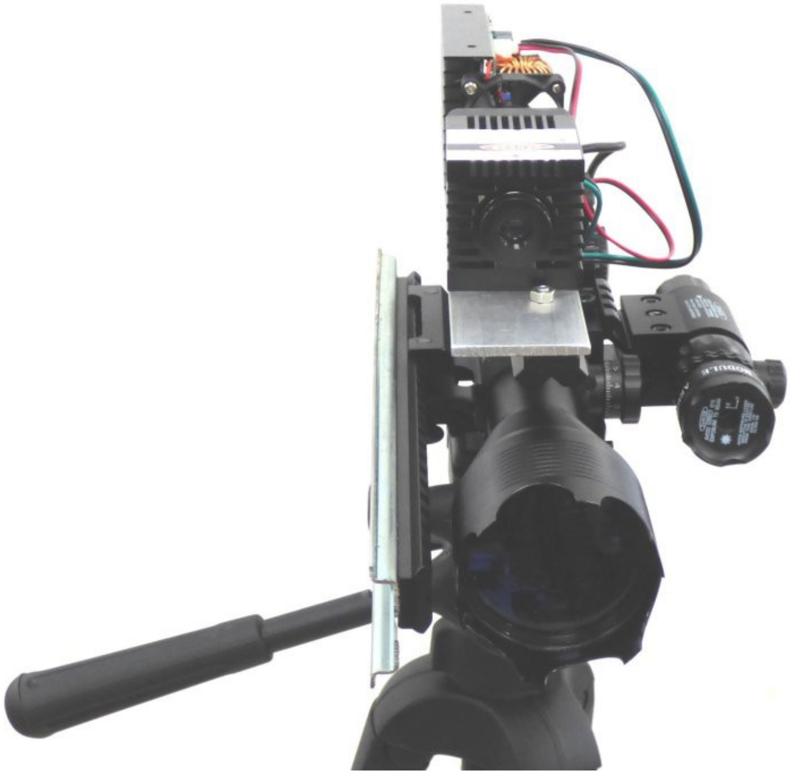


Illustration 3: Front view of the Lasers and Optics

Proof of Principle Equipment – Stage 2

So, how do we improve upon this? Well, the answer is obvious. Rather than relying on the beam straight from the laser passing through the supplied focusing lens we use custom optics to expand and collimate the beam. This at once gives us better control over the divergence and by expanding the beam makes it somewhat safer by reducing areal power density.

Next, we add a receiver to the telescope eyepiece.
This consists of a bandpass optical filter centered at the wavelength of the laser transmitter. Again, this assumes that any VN probe is quite capable of transmitting on the received wavelength at a power level comparable to, or greater than, our own.
The necessary electronics, including a high sensitivity photodiode, is not prohibitively expensive.

Final equipment and Message Format

The above describes a minimal setup both from a cost and capability point of view. A more suitable laser system would be one using a far higher power, and a receiving telescope with a mirror at least 200mm diameter (8” reflector).

The choice of lasers is wide, but if we limit the choice to minimize atmospheric absorption and costly optics that leaves visible and near infrared (NIR).

One possibility stands out. That is a Q-switched Nd:YAG laser[xii], with around a 200W continuous, 1MW pulsed, output at 1064nm normally used as an industrial cutter. The output can if necessary be frequency doubled to 532nm green but with loss of power.

This should be able to communicate with its equivalent to a distance beyond the orbit of Jupiter.

Such systems typically cost under $15k, although the optics, beam guides and alignment equipment will add significantly to this price. Needless to say, such a beam in free space is spectacularly dangerous if mishandled.

Additional requirements will include an electric generator or power source in the kilowatt region, water cooling and a trailer if the equipment has to be moved to an open air site before use.

All together we intend to budget around $30,000 for the hardware. Location is as yet undecided, although a strong possibility is Provo, Utah in the USA given its clear skies and weather. Britain is a poor second in this respect. Plus, we may locate it at the TransHumanist House[xiii] available to Zero State House Adar. However, much depends on location and local laws.

The message format with Q-switched pulses would be somewhat different from the existing setup. The coding would be provided by the timing between the pulses, or by the timing between successive pulse trains. Again, data rate would be low because we are not attempting to communicate anything complex. Just attract attention.

Zero State seeks collaboration from like-minded engineers and scientists, and sponsorship for this project, which after initial hardware costs are met should incur very low running costs.

Ethical Considerations

On 13 February 2015, scientists (including Geoffrey Marcy, Seth Shostak, Frank Drake, Elon Musk and David Brin) at a convention of the American Association for the Advancement of Science, discussed Active SETI and whether transmitting a message to possible intelligent extraterrestrials in the Cosmos was a good idea; one result was a statement, (which was not signed by Seth Shostak or Frank Drake), that a "worldwide scientific, political and humanitarian discussion must occur before any message is sent"[xiv].

We believe that this is not, and should not be the case for local METI. We should issue the invitation to communicate now. It is beyond reasonable doubt that if any ETI capable of receiving these messages lies within our solar system or a few tens of light years, then they already know of our existence.

i https://en.wikipedia.org/wiki/List_of_interstellar_radio_messages
ii http://meti.org/mission
iii https://arxiv.org/abs/1706.05570
iv Journal of the British Interplanetary Society, Vol.33, pp. 251-264 1980
v https://en.wikipedia.org/wiki/Lunar_lava_tube
vi https://en.wikipedia.org/wiki/Lagrangian_point
vii S. Hecht, S. Schlaer and M.H. Pirenne, "Energy, Quanta and vision." Journal of the Optical Society of America, 38, 196-208 (1942)
viii http://www.lasersafetyfacts.com/4/
ix https://sourceforge.net/projects/realterm/
x https://www.maplin.co.uk/p/usb-to-ttl-serial-cable-cable-n74de
xi http://odicforce.com/epages/05c54fb6-7778-4d36-adc0-0098b2af7c4e.sf/en_GB/?ObjectPath=/Shops/05c54fb6-7778-4d36-adc0-0098b2af7c4e/Products/OFL365-5-TTL
xii https://en.wikipedia.org/wiki/Nd:YAG_laser
xiii https://hpluspedia.org/wiki/Transhuman_House
xiv https://en.wikipedia.org/wiki/List_of_interstellar_radio_messages