Optical SETI Introduction/Refresher

Using only “Earth 2000” technology, it is possible to send a brief, directed optical flash to another world that would give the Sun the three orders of magnitude, independent of range. We refer to this remarkable fact as the **Fundamental Theorem of Optical SETI**.

Optical SETI programs do not transmit; they search for such signals.

The Scheme: A transmitting civilization beams their powerful pulsed optical laser at the Solar System using an optical telescope.

**Is this possible?**

- **One possibility:** Use a Helios-like laser ($10^{15}$ W for nanosecond pulse) and a Keck-like telescope (10 meter diameter). The host star puts out ~$4 \times 10^{26}$ W. Thus the laser is briefly brighter by a factor of ~2500!!

- **The receiving civilization (us!)** receives plenty of photons per pulse ($N_x$). When one goes through the calculation, they find (for reasonable parameters) $N_x = 10^{30}$ W. $\lambda = 10^{-6}$ m is the transmitted wavelength and $h,c$ are physical constants.

Receiving Strategy?

- **Fast detectors** to resolve short pulses -- e.g. photomultiplier tubes, photodiodes.

**Why Optical?**

- **Sample detection:** re: spectral filters require no magic frequencies, very little computation required, just fast photon-counting detectors.

- **Natural Choice:** emerging civilizations would likely survey optical wavelengths (and 21-cm radio, etc.) for natural phenomena. This makes it a natural choice for the transmitting civilization.

- **Directivity:** optical telescopes can form much tighter beams than radio telescopes, i.e narrow targeting.

- **Minimal dispersion:** short optical pulses are not significantly dispersed by the interstellar medium.

- **Recent progress:** many high security selling capacity at optical frequencies.

- **But:** range is limited to ~20 pc in the work due to attenuation (~10^5 stars in this volume) -- IR better.

Potential Pulsed Optical Backgrounds:

- **Sky/Atmosphere:** possible to detect Carrenkov radiation from cosmic-rays with very large apertures.

- **Stellar:** stars are dark on short timescales. Photon pulse rate: Sun-like star at 1000 ly:

  - 10^6 photons/km^2 s at 1 m photodiode.

- **Other Astrophysics:** probably none with nanosecond timescale; would require enormous power from centimeter-sized region.

**Instrumental/Detector:** can be problematic -- corona discharge, stimulated in glass, Cosmic-rays, etc.

- All backgrounds appear to be manageable or negligible.

Oak Ridge Observatory - 3 SETI Expts

- Located in Harvard, MA, home to three SETI experiments -- all-sky optical SETI, targeted optical SETI, BETA (all-sky radio SETI).

- Spectroscopic radial-velocity survey for planets and brown dwarfs also on site.

- Many thanks to the observers for their efforts and support -- Robert Stefanik, Dave Latham, Joe Zajac, Joe Caruso.

Observatory

- Building is 9m x 5m -- a steel truss structure with wood facade.

- Houses new 72” telescope.

- Two rooms -- telescope “pit” and control room.

- Roof rolls North on support structure for telescope viewing.

- Building is 9m x 5m -- a steel truss structure with wood facade.

Electronics

- **Photodetectors**
  - Single photons are converted to nanosecond electrical pulses for processing in downstream electronics.
  - We use multi-anode photomultiplier tubes (PMT) from Hamamatsu.
  - 64 independent pixels per PMT -- allows for 1024 total pixels.
  - Fast time response (nanosecond speed) for photon counting.
  - Broad spectral sensitivity with modest quantum efficiency (~25%).
  - Modest pulse height resolution -- difficult to distinguish one from a few incident photons.
  - Each PMT pixel covers a 1.5 x 1.5 arcminute area on the sky.

- **Electronics**

  - The “camera” (in design) will integrate sixteen 64-pixel PMTs, thirty-two PulseNet chips, control electronics, and beam splitting and folding optics to form the eyes and brain of the experiment.

- **Basic functions:** collect visible light from 512 pixels on the sky, convert the incoming photon stream into digital data, filter the data for large coincident pulses, and record interesting events.

- **Details:**
  - The 512 pair of PMT pixels are matched so that each pair sees the same part of the sky.
  - The data processing for every pair of 64-pixel PMTs is handled by four PulseNet chips (below).
  - “Coincidence” microcontrollers will program the PulseNets (set threshold levels, modes, etc.), transfer coincident pulse data from the PulseNets to external computers, and monitor the experiment.
  - “Astrometry” microcontrollers will constantly cycle through pixel pairs (via their PulseNet connections) recording count rates (proportional to photon flux) so as to map the sky and follow particular stars.

- **Potential Pulsed Optical Backgrounds:**
  - Stellar: probably none with nanosecond timescale; would require enormous power from centimeter-sized region.

- **Output:**
  - The PMTs output for pulsed optical beacons. Its meridian transit survey mode requires ~150 clear nights to cover the Northern sky with ~1 minute dwell time per source point. It images a 1.6 x 0.2 degree field.

- **PulseNet - a full-custom chip for OSETI**

  - A full-custom ~200,000 transistor integrated circuit
  - Designed in collaboration with Bill Daily’s VLSI group in the Computer System Laboratory at Stanford University. “Tape-out” in weeks.

- **Functions:** samples the analog PMT outputs with flash digital converters; identifies coincident optical flashes; records and outputs the waveforms of these flashes; also provides photon count rates used for sky imaging.

- **Details:**
  - Each PulseNet will handle sixteen pair of PMT pixels; 32 PulseNets are required in all.
  - The samples are 7-level flash converters based on 3-threshold (sense amp) latches operating at 500 MHz (with two phases) for 1 GSP. They produce “thermometer” codes.
  - The 7-bit thermometer code is encoded to 3-bit Gray code, and is delayed in shift register banks while synchronous logic blocks for pixel pairs that simultaneously exceed a set level (the coincidence requirement).
  - When an event occurs, the Gray-Binary waveform digitized from the coincident pixel pair is piped into a 512-bit deep shift register memory.
  - A SETI ID module notifies external electronics of events and orchestrates the export of waveform data.
  - Additionally, an “astrometry” module on PulseNet counts the number of times that a particular level is exceeded for a particular pixel pair. This will allow us to measure the photon flux on individual pixels, and thus map the sky and perform system checks.

- **System Overview**

  - All-sky survey is essentially a multiplexed elaboration of the targeted search at Harvard (schematically depicted in the upper left under “Is This Possible?”) -- 512 copies of the targeted search operating in parallel over a much larger field of view.

  - Each pair of pixels observe a 1.5 x 1.5 arcminute patch of sky -- a total of 1.6 x 0.2 -- for optical pulses.

  - Optical splits the incoming light beam and coincidence is required between paired pixels to reduce the false alarm rate.

  - Fixed hour angle telescope for meridian transit survey (1-axis mount) skews through with each point on the sky being observed for a minimum of 48 seconds.

  - Two arrays of multi-pixel photomultiplier tubes will do the light detection.

  - Custom electronics, including a custom chip called ‘PulseNet’ will monitor the photodetector outputs for nanosecond scale flashes in paired pixels.

- **Telescope**

  - The 72” spherical f/2.5 telescope was delivered in February, 2002.

  - “Light bucket” optical quality -- ~2 arcminute resolution -- which matches the pixel size on our photodetectors.

  - Moves in declination only -- sky drifts through in meridian transit mode.

  - Incoming optical beam is split into two identical beams; we look for coincident optical pulses in each beam to reduce the background event rate.

  - Detector package (to be built) will be mounted in the focal plane and will image a 1.6 x 0.2 patch of the sky using two arrays of 64-pixel photomultiplier tubes.

- **Support from:** Planetary Society, Bosack-Kruger

  - Charitable Foundation, SETI Institute, MOSIS Service

  - All-sky optical SETI observatory is a 1.8 meter spherical f/2.5 optical telescope, soon to survey the Northern sky (~20° < δ < +60°) for pulsed optical beacons. Its meridian transit survey mode requires ~150 clear nights to cover the Northern sky with ~1 minute dwell time per source point.

  - Each two focal planes with a super-Keck 10 meter telescope to image a 1.6 x 0.2° patch of the sky using two arrays of 64-pixel photomultiplier tubes.