BRIEFING 08 · BRAIN & NEUROTECH

DARPA Firefox: reading the brain with light, no surgery

A deep dive into non-invasive brain-computer interfaces: why surgery has been needed, how optical interferometry and analog computing could change that, what DARPA's Firefox program targets, and the privacy questions it raises.

Mohsin Khan Shaik
AI Infrastructure & Site Reliability Engineer · San Francisco · mohsinkhanshaik.com
Edition of 2026-11-22

08 · BRAIN & NEUROTECH

DARPA Firefox: reading the brain with light, no surgery

A deep dive into non-invasive brain-computer interfaces: why surgery has been needed, how optical interferometry and analog computing could change that, what DARPA's Firefox program targets, and the privacy questions it raises.

100	50 µm	100 µs	36 months
channels, non-invasive	spatial resolution goal	temporal resolution goal	three 12-month phases

Key takeaways

- Firefox is a DARPA Biological Technologies Office program to build a 100-channel non-invasive BCI with 50-micron spatial and 100-microsecond temporal resolution.
- Its two key ideas: dynamic optical scanners that read multiple brain regions at once, and analog computing that processes the data instantly.
- It builds on research detecting neuron firing in human cortex with coherent optical interferometry through a fiber on the scalp.
- Today's best BCIs need brain surgery; a non-invasive device at this resolution would be a major leap.
- Easy-to-wear brain reading makes mental privacy and consent urgent policy questions.

Background: the non-invasive problem

Brain-computer interfaces read neural activity and turn it into commands. Implants like Neuralink's or Utah arrays sit in or on the brain and record individual neurons, but require surgery. Non-invasive methods such as **EEG** (electrodes on the scalp), **fNIRS** (near-infrared light measuring blood oxygen), and **MEG** (magnetic fields) are safe, but the skull blurs signals and blood-flow measures are slow. DARPA's earlier N3 program (Next-Generation Nonsurgical Neurotechnology, 2018) pushed in this direction; Firefox targets far higher resolution.

What Firefox targets

- **Goal:** a 100-channel non-invasive BCI with 50-micron spatial and 100-microsecond temporal resolution [1][2].
- **Innovation 1:** dynamic optical scanners capable of reading multiple brain regions simultaneously [1].
- **Innovation 2:** novel analog computing to process the massive data streams instantly [1].
- **Structure:** 36 months in three 12-month phases with two parallel technical areas; solicitation DARPA-PS-26-137; program manager Dr. Pedro Irazoqui; proposers day in September 2026 [2][3].

How optical brain reading works

When neurons fire, tiny changes in tissue (cell swelling, refractive index, scattering) affect how light travels through it. Coherent optical interferometry compares light that passed through tissue with a reference beam; small changes in phase reveal activity. DARPA notes prior work that extracted the phase

velocity of a small population of neurons firing in human cortex from a non-invasive fiber on the scalp [2]. Scaling that to 100 channels needs fast beam steering (scanners), massive parallel detection, and processing at the sensor, hence analog computing.

Why analog computing

High-resolution optical signals at microsecond timing produce enormous data rates. Digitizing and shipping everything to a computer costs power and latency. Analog front-ends can filter and extract features directly from the signal before digitizing, the same edge-versus-cloud trade-off seen in AI infrastructure.

How it could change life

- **Communication:** people with paralysis or ALS could type or speak through a wearable device without surgery.
- **Diagnosis:** a new window on brain function for epilepsy, stroke recovery and neurodegenerative disease.
- **Rehabilitation:** real-time feedback that helps retrain the brain after injury.
- **Interaction:** hands-free control of computers, vehicles and robots.

Future scenarios

2027	2029	2032	2035+
Phase 1: scanner and analog-processing prototypes in the lab.	Integrated systems approach the 100-channel target in human studies.	Clinical research devices for communication and diagnosis.	Wearable optical BCIs, if size, cost and robustness follow.

- **Optimistic:** near-implant performance without surgery transforms assistive technology.
- **Base case:** meaningful gains over EEG/fNIRS for research and clinical diagnostics.
- **Pessimistic:** scattering through skull and scalp limits resolution far below the target.

Effects and risks

- **Mental privacy:** non-invasive means easy to deploy and potentially easy to misuse; neural data needs strong legal protection and consent.
- **Physics:** light scatters heavily in tissue; hitting 50-micron resolution non-invasively is extremely hard.
- **Equity:** affordable wearables could democratize BCIs, but only if medical access is prioritized.
- **Dual use:** defense interest in human–machine teaming raises ethical questions.

What to watch

- Firefox awards and Phase 1 results.
- Peer-reviewed demonstrations of optical single-neuron-scale signals through the skull.
- Neural-data privacy laws at state and federal level.

My take

Firefox combines two bets I find compelling: optics for sensing and analog compute at the edge. Even partial success would produce valuable spin-offs in medical imaging and sensor processing. The policy

work on neural privacy should start now, before the devices arrive.

Key players & programs

DARPA BTO Firefox	100-channel non-invasive BCI program (2026) [1][2]
DARPA N3 (2018)	Earlier nonsurgical neurotechnology program
Research groups	Optical interferometry, fNIRS, OPM-MEG and functional ultrasound for brain sensing

Frequently asked questions

What is DARPA Firefox?
A DARPA program to build a 100-channel non-invasive brain-computer interface with 50-micron spatial and 100-microsecond temporal resolution, using optical scanners and analog computing.

Is Firefox related to the Firefox web browser?
No. Firefox is the name of a 2026 DARPA neurotechnology program in the Biological Technologies Office.

How can light read the brain?
Neural activity slightly changes how light travels through tissue; coherent optical interferometry detects those tiny changes, even through a fiber placed on the scalp.

Why is non-invasive important?
Today's highest-performance BCIs need brain surgery. A wearable device with similar detail would be safer and far more widely usable.

Glossary

EEG: Electroencephalography: measuring electrical activity with electrodes on the scalp.

fNIRS: Functional near-infrared spectroscopy: measuring blood-oxygen changes with light.

Interferometry: Measuring tiny changes by comparing the phase of two light beams.

Analog computing: Processing continuous signals directly, without converting them to digital numbers first.

References

1. DARPA — Firefox program page
   https://www.darpa.mil/research/programs/firefox
2. DARPA — Firefox FAQ (Oct 2026)
   https://www.darpa.mil/sites/default/files/attachment/2026-10/darpa-program-firefox-faq.pdf
3. DARPA-SN-26-112 Amendment 01 (proposers day)
   https://everglade.com/wp-content/uploads/DARPA-SN-26-112-Amendment-01.pdf