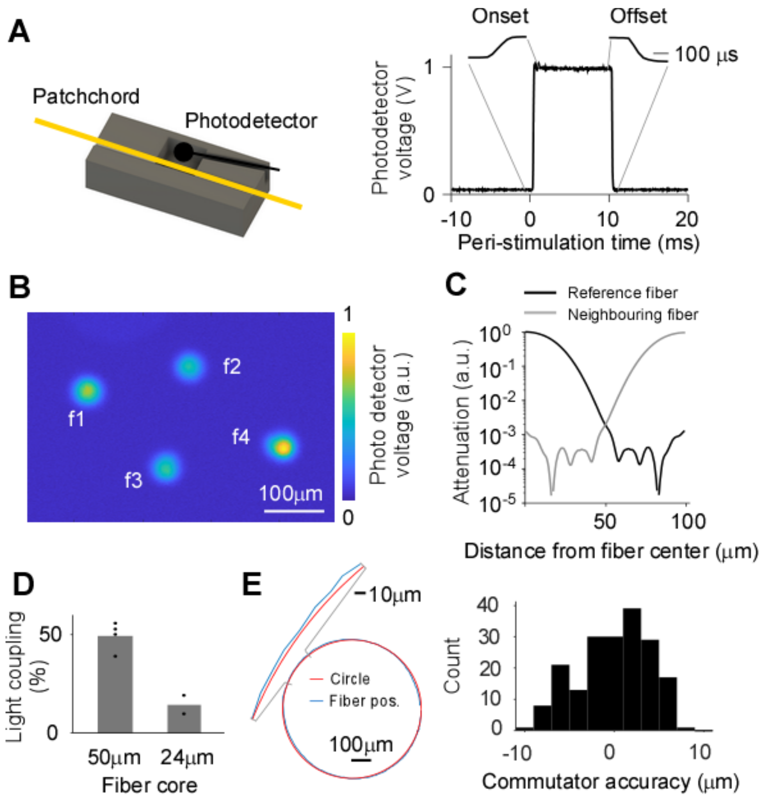
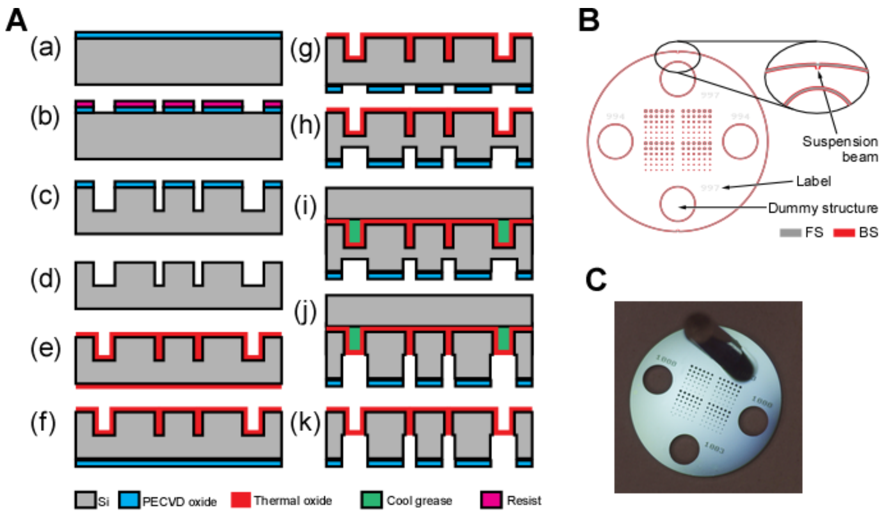
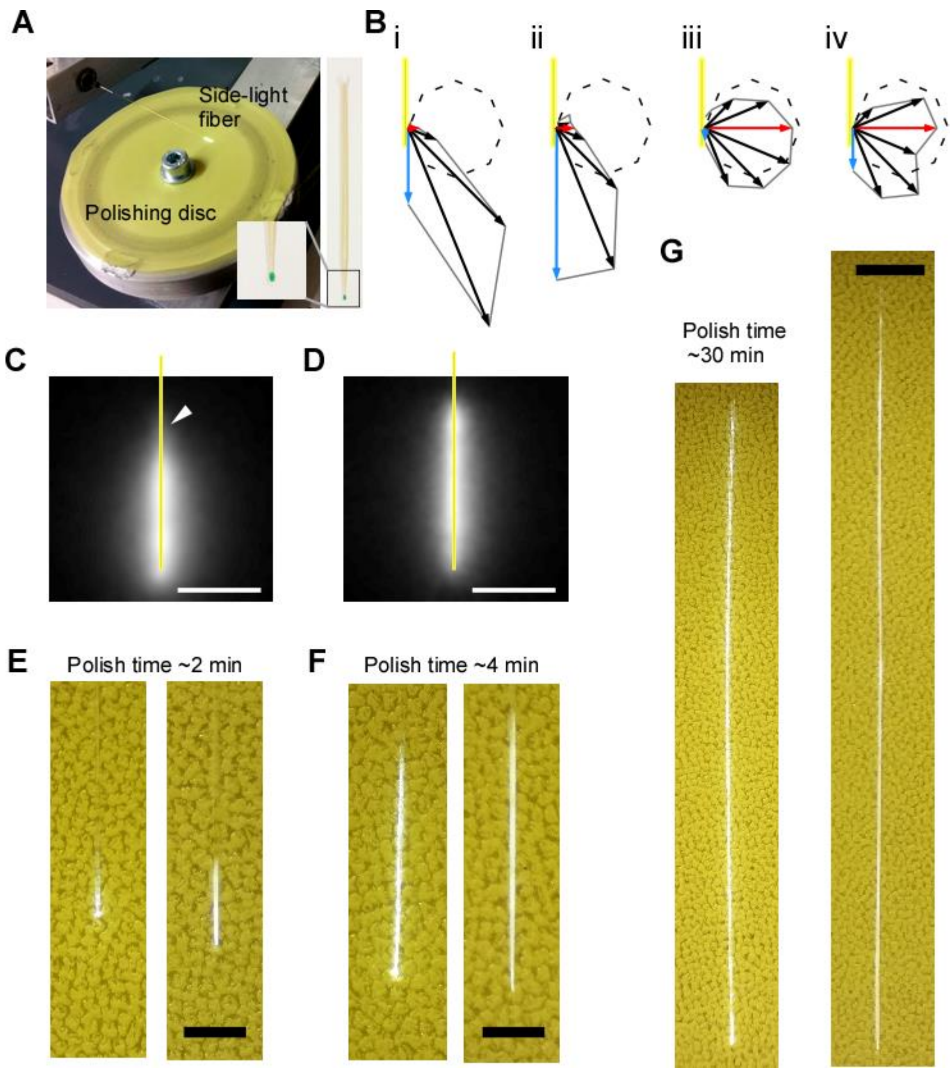


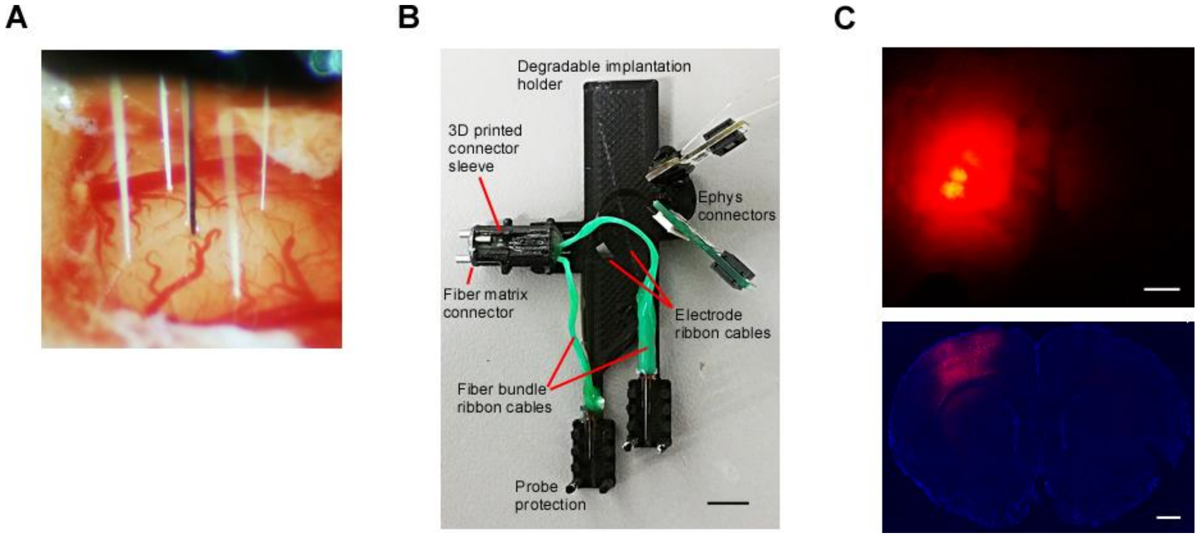
Supplementary Figure 1. Active patch cord and optical commutator. A: To be able to tune the laser system in the freely moving animal and to automatically find the fiber locations, we attached a linear photodetector to the patch cord. A fraction of the light from the fibers was transmitted through the patch cord furcation tube and detected by the photodiode (left panel). The rapid targeting of the fibers was detected with the photodiode (right panel). B: Example readout from the active patch cord while the galvo scanner mapped four fibers in the ferrule. Scale bar, 100 µm. C: The optical isolation of one fiber (black line) and the mirrored version (gray line) suggests that two fibers with a separation of 100 µm can be individually addressed. D: Input laser power at ferrule divided by output power after passing the patch cord. E: Mechanical stability of the optical commutator. Red circle is the ideal rotation and the blue circle is the center of the optical fiber. Zoomed in section indicates minimal deviations (left). Deviation between ideal position and true fiber position (right).



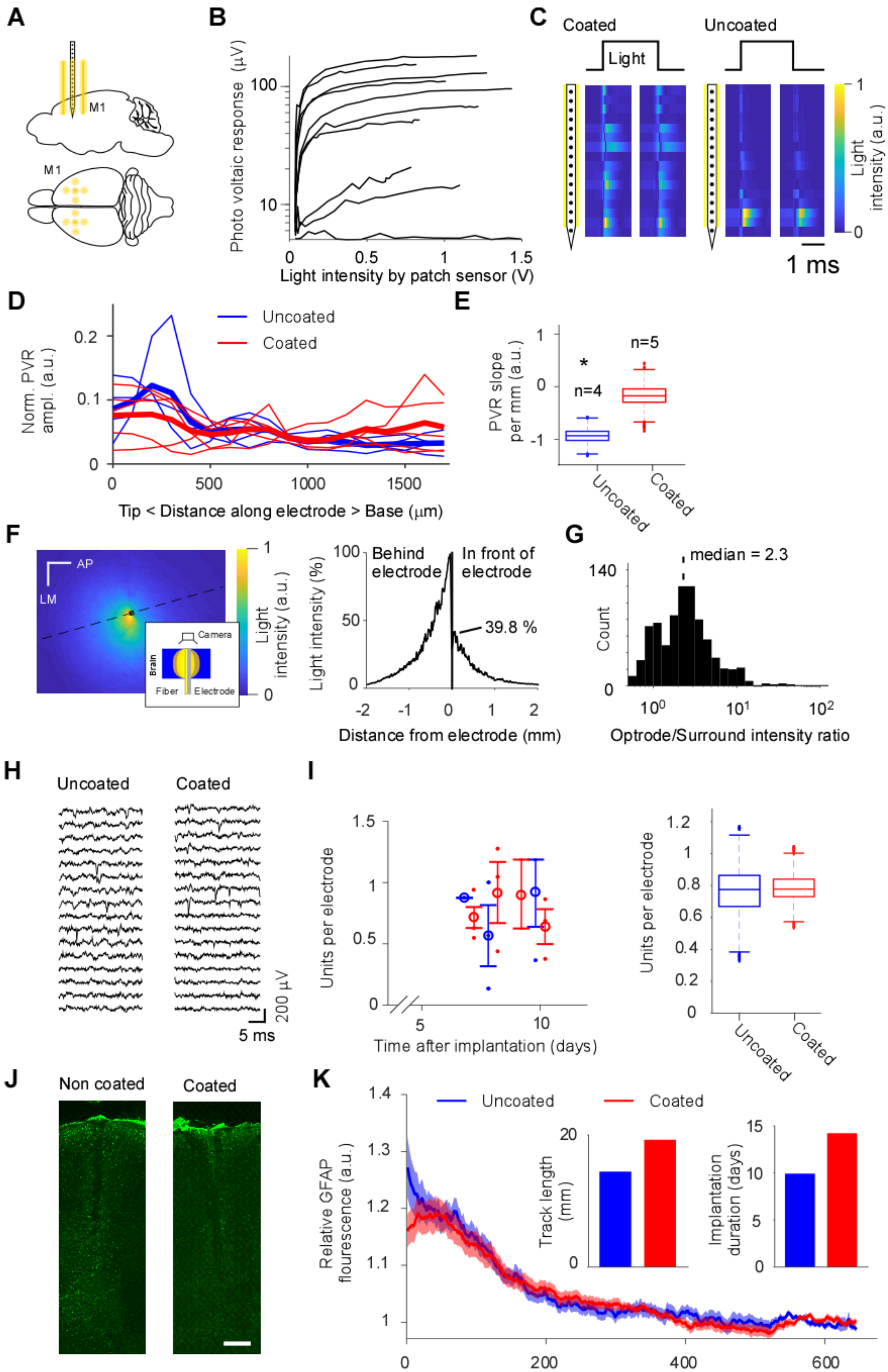
Supplementary Figure 2. Fiber matrix connector. A: Main processing steps to realize the Si-based connector plates of the fiber connector: (a) Deposition of PECVD SiO_x masking layer on wafer front side (FS), (b) patterning of SiO_x using lithography and RIE, (c) FS DRIE to an etch depth of 200 µm, (d) wet chemical etching of SiO_x layer, (e) thermal oxidation, (f) deposition of 2 µm SiO_x in wafer rear side (RS), (g) patterning of RS SiO_x, (h) DRIE to 150 µm etch depth, (i) wafer fixation on handle wafer using Cool Grease, (j) DRIE etch through, and (k) release from handle wafer. B: The layout of the lithography mask of a connector plate. The gray polygons indicate those areas patterned by deep reactive ion etching from the wafer FS. The etch pattern from the wafer BS was achieved by adding the gray and red polygons. The larger outer ring defined the plate geometry. The structures on the top and bottom indicate beams that suspend the connector plate inside the silicon wafer during the entire fabrication process. Each plate with a diameter of 5 mm comprises two pairs of circular through-holes with equal diameters of ca. 1 mm. One pair of holes will be used for guide-pins and the other pair will be used for anchoring pins. The anchoring pins anchor the plate in the connector sleeve and the fiber bundle.



Supplementary Figure 3. Manufacturing and types of side-emitting optical fibers. A: Polishing plate for manufacturing side-emitting fibers. B: Emission angle of uncoated fiber (i), uncoated fiber glued to a transparent thin film (ii), coated fiber (iii), and coated fiber glued to a transparent thin film (iv) plotted in relation to a Lambertian distribution (dashed circle). Note that the coating enhances the side-emitting component (red arrow) in relation to the forward component (blue arrow). For side-emitting fibers glued onto a transparent thin film laminar electrode, the fiber coating ensures that the light was transmitted through the thin film (red arrow in the fourth panel) rather than to the front (blue arrow in the second panel). Dashed circle describes an ideal Lambertian emitter. C: An uncoated two millimeter fiber in milk. Scale bar, 1 mm. D: A coated two millimeter fiber in milk. Scale bar, 1 mm. E-G: Uncoated (left) and coated (right) fibers polished for a length of 0.5, 2, and 10 mm, respectively. Scale bar, 500 µm, 500 µm, and 1 mm, respectively.



Supplementary figure 4. Implantation of multiple fibers and electrodes. A: The brain dimpling was barely detectable when inserting the fibers and electrodes. The BE-probe, consisting of a silicon electrode next to two side-emitting fibers, is surrounded by four additional side-emitting fibers (fiber matrix). B: Temporary implant holder for individual targeting of multiple brain areas with multiple BE-probes and additional fibers. Scale bar, 5 mm. C: In vivo mCherry expression (AAV-hSyn-eNpHR3.0-mCherry-WPRE, 561nm excitation light at 610nm low pass collection filter) was used to guide the implantation (upper panel, view from the top onto the brain’s surface). Corresponding coronal section at bregma 1.2 mm (lower panel). Scale bar, 1 mm.



A
M1
M1
B
Photo voltaic response (μV)
100
10
0
0.5
1
1.5
Light intensity by patch sensor (V)
C
Coated
Uncoated
Light
1
Light intensity (a.u.)
0
1 ms
D
Uncoated
Coated
Norm. PVR ampl. (a.u.)
0.2
0.1
0
0
500
1000
1500
Tip < Distance along electrode > Base (μm)
E
PVR slope per mm (a.u.)
1
0
-1
*
n=4
n=5
Uncoated
Coated
F
AP
LM
Camera
Brain
Fiber
Electrode
1
Light intensity (a.u.)
0
Light intensity (%)
100
50
0
Behind electrode
In front of electrode
39.8 %
-2
-1
0
1
2
Distance from electrode (mm)
G
median = 2.3
140
Count
0
10^0
10^1
10^2
Optrode/Surround intensity ratio
H
Uncoated
Coated
200 μV
5 ms
I
Units per electrode
1.5
1
0.5
0
5
10
Time after implantation (days)
Units per electrode
1.2
1
0.8
0.6
0.4
0.2
0
Uncoated
Coated
J
Non coated
Coated
K
Uncoated
Coated
Relative GFAP flourescence (a.u.)
1.4
1.3
1.2
1.1
1
0
200
400
600
Distance from fiber track (μm)
Track length (mm)
20
0
Implantation duration (days)
15
10
5
0

Supplementary Figure 5. BE-probe performance in the freely moving animal. A: Implanted BE-probes and fiber matrices. B: Assessing the BE-probe functionality using the Photo Voltaic Response (PVR) to make sure that the fibers are intact. C: Example PVR distribution along the electrode for coated and uncoated fiber. D: The PVR along the electrode shank for all coated and uncoated fibers. E: Quantifying the light emission along the electrode for the uncoated and coated fiber by means of the slope of the PVR along the electrode (see panel E). A negative slope is associated with a stronger PVR towards the tip. F: The light distribution of yellow light (589 nm) across the cortical surface from a vertical BE-probe in the motor cortex of a freshly cut mouse brain (left panel). A roughly 5 mm thick transverse slice was put horizontally and was penetrated from below by a BE-probe such that the light distribution could be imaged on the cortical surface from above (left panel, inset). Intensity cross-section (dashed line in the left panel) to compare the light intensity at the electrodes and the fibers (right panel). Scale bar, 0.5 mm. G: Comparing the PVR for BE-probe fibers and fiber matrix. The relative light intensity caused by BE-probe fibers are larger than those of the fiber matrix. H: Examples of extracellular signals for an uncoated fiber and for a coated fiber. I: Quantification of electrophysiology quality as a function of days after implantation and coated (red) versus non-coated (blue) fiber-electrode combinations. J: Representative histological examples for GFAP immunostaining (green) for uncoated and coated fibers after 11 days of implantation. Scale bar, 200 µm. K: Histological quantification of the GFAP signal as a distance to the BE-probe.