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Supporting Information for

Airy-beam holographic sonogenetics for advancing neuromodulation precision and flexibility

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This PDF file includes:

Figures S1 to S5

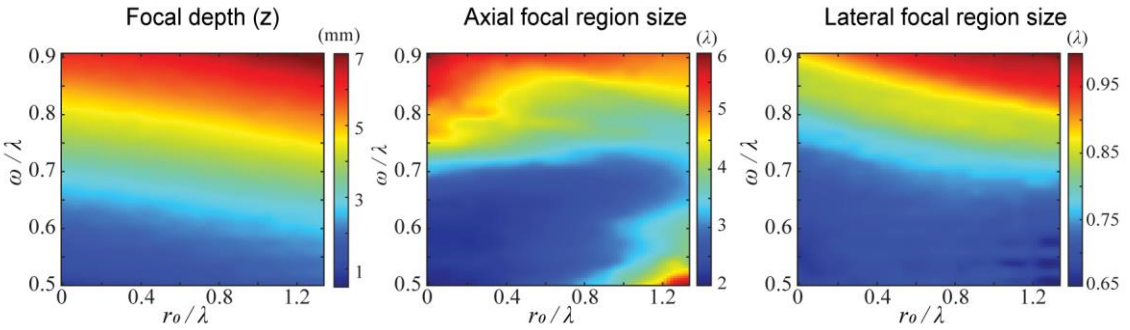

Fig. S1. Airy-beam metasurface's focusing properties are tunable by adjusting design parameters. The focal characteristics of the Airy-beam metasurface—specifically, focal depth, axial focal region size, and lateral focal region size—are influenced by the parameters ω and r0, normalized to the wavelength λ. Simulations demonstrate that by varying ω/λ and r0/λ, the metasurface's focusing properties can be precisely adjusted. At an operational frequency of 3.0 MHz, with r0/λ ranging from 0 to 1.3 and ω/λ from 0.5 to 0.9, we can modulate the focal depth between 0.5 mm and 7.0 mm. The axial and lateral focal region sizes can be tuned between 2.0λ to 6.0λ and 0.65λ to 0.98λ, respectively.

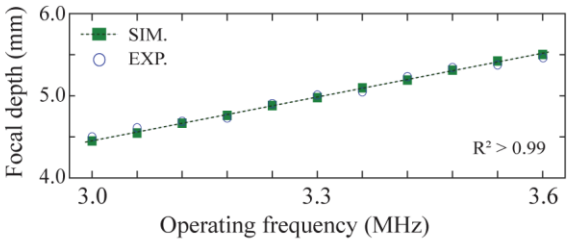

Fig. S2. Calibration of the wearable ultrasound device using hydrophone measurements. Calibration graph depicting the correlation between focal depth and operating frequency for the Airy-beam metasurface (referenced in Fig. 1d, e). The plotted data, featuring simulation outcomes (solid squares) and empirical hydrophone measurements (open circles), corroborate that the device's focal depth is adjustable via changing the operating frequency of the ultrasound.

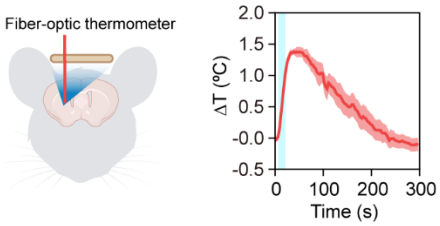

Fig S3. Airy-beam holographic ultrasound induced a mild temperature rise at the target. Left: illustration of the experimental setup for measuring the temperature at the ultrasound target region using a fiber-optic thermometer. Right: Temperature increase at the target with the shaded vertical blue-color bars indicating the ultrasound ON time. Solid red lines and shadows indicate the mean and s.e.m.

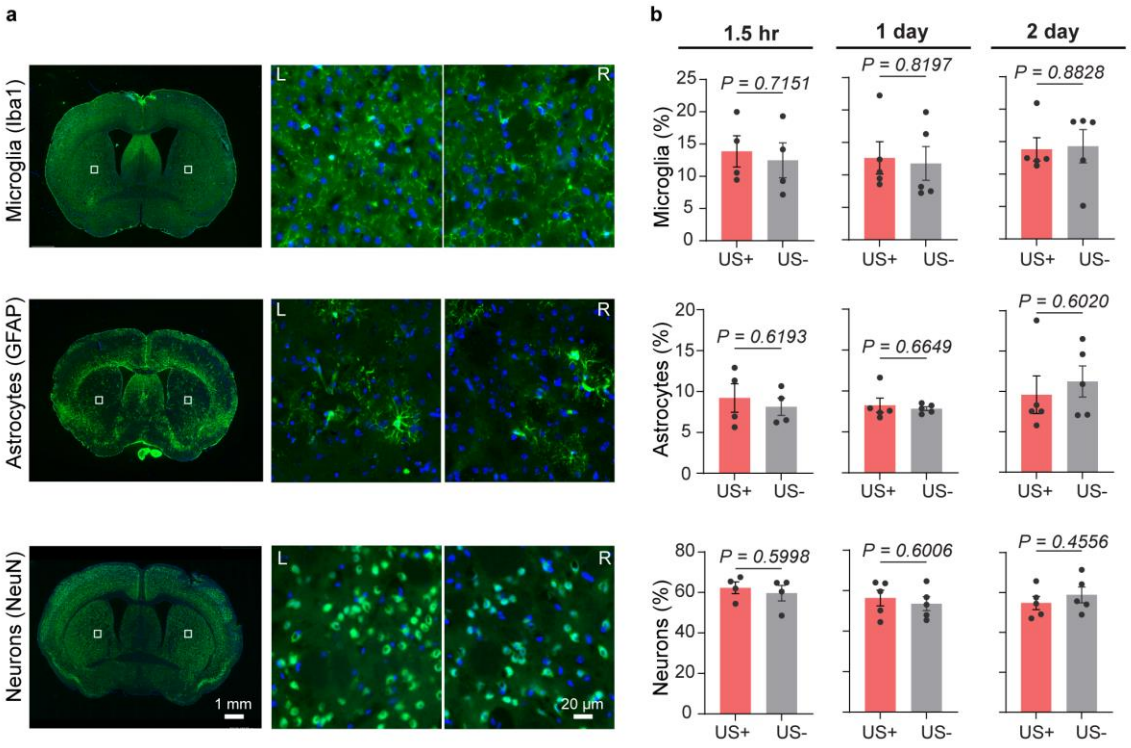

Fig. S4. Evaluation of AhSonogenetics safety. a, Representative fluorescence microscopy images displaying immunohistochemical staining of microglia, astrocytes, and neurons post-AhSonogenetic stimulation, using Iba1, GFAP, and NeuN as specific markers, respectively in the mice sacrificed 1.5 hours after ultrasound sonication. Iba1, GFAP, and NeuN are represented as green color while the blue color indicates DAPI. b, Comparative quantification of neuron, astrocyte, and microglia populations in the ultrasound-targeted left striatum (US+) versus the unstimulated contralateral right striatum (US-) of mice sacrificed at different time points after ultrasound sonication including 1.5 hours, 1 day and 2 days. The standard error of the mean is represented by error bars, with each point symbolizing an individual mouse (n = 4 mice for 1.5 hr group, n = 5 for 1 day and 2 days groups). Statistical significance was determined using an unpaired two-tailed t-test to calculate *P* values.

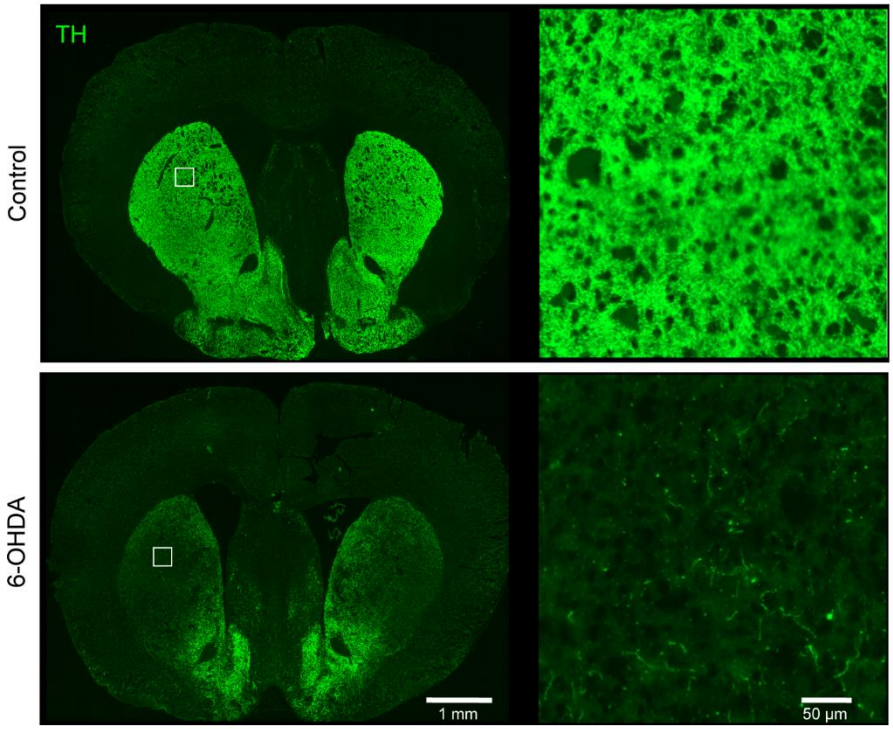

Fig. S5. Confirmation of striatal dopamine depletion in Parkinson's disease mouse model. Immunofluorescence staining for tyrosine hydroxylase (TH) showcases the striatal TH levels: contrast is evident between the dopamine-depleted bilateral striatum of the Parkinsonian mice (bottom panel) and the intact striatum of healthy control mice (top panel).