

# A. Magnetic / MRI-Related (Non-Invasive)

1. **Functional Connectivity MRI (fcMRI)**  
Not the same as BOLD; uses correlation structure across voxels. (Probably implicit, but useful to explicitly list.)
2. **Resting-State fMRI (rs-fMRI)**  
Now its own category of technique with unique analytical methodology.
3. **Magnetic Particle Imaging (MPI)**  
A new imaging modality using superparamagnetic nanoparticles for high temporal resolution neurovascular imaging.
4. **Susceptibility-Weighted Imaging (SWI)**  
Useful for venous blood mapping and hemodynamic activity in vivo.
5. **Quantitative Susceptibility Mapping (QSM)**  
Reconstructs iron content and hemodynamic changes related to function.
6. **Functional MRS (fMRS)**  
Measures neurotransmitter fluctuations (Glu, GABA) in vivo in real time.
7. **Magnetic Resonance Elastography (MRE)**  
Measures brain tissue stiffness changes associated with neural activity and neurovascular coupling.
8. **Chemical Exchange Saturation Transfer (CEST) fMRI**  
Detects metabolites and neurotransmitters via exchangeable protons, providing molecular functional imaging.
9. **Microvascular Volumetric Pulsatility Mapping**  
Combines VASO and ASL at ultra-high field to map pulsatile flow in cerebral microvessels linked to activity.
10. **Neurite Orientation Dispersion and Density Imaging (NODDI)**  
Multicompartment diffusion MRI model to estimate neuronal microstructure and density in vivo.
11. **Neuromelanin-Sensitive MRI**  
Detects neuromelanin in substantia nigra and locus coeruleus as a proxy for catecholaminergic neuron function.
12. **Free-Water Diffusion Imaging**  
Removes extracellular free water contributions from diffusion signals to assess
13. **Optically Pumped Magnetometer MEG (OPM-MEG)**  
Room-temperature, scalp-proximate optically pumped magnetometer arrays for high-sensitivity, flexible MEG recordings in naturalistic and mobile settings.
14. **Hyperpolarized <sup>13</sup>C Metabolic MRI**  
Real-time metabolic flux imaging using hyperpolarized <sup>13</sup>C tracers to measure rapid changes in brain energy metabolism linked to neural activity.
15. **[NEW] Magnetic Resonance Fingerprinting (MRF)**  
Rapid, quantitative multiparametric tissue mapping for assessing dynamic physiological changes during brain activity.
16. **[NEW] VASO (Cerebral Blood Volume fMRI)**  
Non-BOLD fMRI technique sensitive to cerebral blood volume changes for layer-specific functional imaging.

17. **[NEW] Q-ball Imaging**  
High angular resolution diffusion imaging (HARDI) technique for resolving complex fiber crossings in white matter.
  18. **[NEW] Continuous Arterial Spin Labeling (CASL)**  
Non-invasive perfusion MRI method using continuous RF inversion of arterial water for quantitative CBF mapping.
  19. **[NEW] Pulsed Arterial Spin Labeling (PASL)**  
ASL variant using short RF pulses to label arterial blood, offering different trade-offs for perfusion imaging.
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## B. PET / Radiotracer Advances

20. **Fiber-Coupled PET Detectors (minimally invasive)**  
Enables localized in vivo PET from freely moving animals.
21. **Neuroimmune PET Ligands (TSPO, CSF1R etc.)**  
For studying microglial/astrocyte activation dynamically. (Not purely activity, but increasingly part of functional neuroimaging.)
22. **Total-Body PET Imaging**  
Enables whole-brain dynamic imaging with unprecedented temporal resolution and sensitivity.
23. **Positronium Lifetime Imaging**  
Emerging PET technique providing information about tissue microenvironment during neural activity.
24. **Synaptic Vesicle Glycoprotein 2A (SV2A) PET Imaging**  
Uses tracers like [<sup>11</sup>C]UCB-J to quantify synaptic density in vivo.
25. **Mitochondrial Complex I PET Imaging**  
Employs [<sup>12</sup>F]BCPP-EF to assess mitochondrial function and energy metabolism related to neural activity.
26. **CSF1R PET for Neuroinflammation**  
Tracers like [<sup>11</sup>C]CPPC to image microglial activation during brain processes.
27. **Positron Emission Metabolic Tracing with Short-Lived Isotopes (rapid kinetic PET)**  
High-temporal-resolution PET protocols using short-lived radiotracers and fast kinetic modeling to track sub-minute metabolic changes associated with neural events.
28. **[NEW]  $\mu$ -opioid Receptor PET ([<sup>11</sup>C]carfentanil)**  
In vivo imaging of endogenous opioid release during various behavioral states.
29. **[NEW] Dopamine D2/D3 Receptor Occupancy PET**  
Measures dynamic changes in dopamine transmission using radioligands like [<sup>11</sup>C]raclopride.
30. **[NEW] Cerebral Metabolic Rate of Oxygen (CMRO<sub>2</sub>) PET**  
Quantitative imaging of oxygen metabolism coupled to neural activity using <sup>15</sup>O-labeled tracers.
31. **[NEW] Astrocyte-Specific PET Tracers (<sup>11</sup>C-deuterium-L-deprenyl)**  
Targets monoamine oxidase B in astrocytes for glial activity mapping.

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## C. Electrophysiology & Implant Technologies

32. **Neuropixels Probes (latest gen)**  
Not just "multielectrode"; Neuropixels constitute a distinct class due to ultra-high channel count (1,000+), used in vivo widely.
33. **Silicon Probe Laminar Recordings**  
For cortical column laminar activity (V1, CA1).
34. **High-Density "ECoG Grids" (Neuropixels–ECoG hybrids)**  
New grids with thousands of micro-electrodes recordings across cortex.
35. **EMG-Assisted Brain–Body Coupled Recording**  
Used in behaving animals to integrate motor output with neural activity.
36. **Flexible Bioelectronic Neural Interfaces**  
Conformable electrode arrays that minimize tissue damage and enable stable long-term recordings.
37. **Transparent Graphene Microelectrode Arrays**  
Allow simultaneous electrical recording and optical imaging/optogenetics.
38. **Ultrasonic Neural Dust Motes**  
Wireless, millimeter-scale implants for chronic neural recording.
39. **Optetrode Recordings**  
Hybrid probes combining electrical electrodes with optical fibers for simultaneous recording and stimulation.
40. **CMOS-Integrated Neural Probes**  
On-chip amplified high-density probes for low-noise in vivo recordings.
41. **Sharp Electrode Intracellular Recordings**  
Historical method using fine glass micropipettes for high-impedance intracellular potential measurements.
42. **Wireless High-Density Neural Probes (wireless Neuropixels variants)**  
Fully wireless, implantable high-channel-count probe systems enabling untethered large-scale neural recordings in freely moving animals.
43. **Autonomous Robotic In Vivo Patch-Clamp (AutoPatch / Robopatcher)**  
Automated robotics-enabled intracellular patch-clamp in awake or anesthetized
44. **Graphene Field-Effect Transistor Neurochemical Sensors (gFETs)**  
Implantable gFET biosensors for direct, high-sensitivity, real-time detection of neurotransmitters and neuromodulators in vivo with electrical readout.
45. **[NEW] Tetraode Recordings**  
Historical method using four-wire bundles for extracellular recording with improved single-unit isolation.
46. **[NEW] Juxtacellular Recording and Labeling**  
Technique for extracellular recording followed by intracellular labeling of recorded neurons.

47. **[NEW] Carbon Fiber Microelectrodes**  
Miniaturized electrodes for electrochemical detection of neurotransmitters with fast-scan cyclic voltammetry.
  48. **[NEW] Floating Microelectrode Arrays**  
Untethered microelectrodes that move with brain tissue for stable chronic recordings.
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## D. Optical / Imaging-Based Techniques

49. **Light-Sheet Fluorescence Microscopy (LSFM) In Vivo**  
Now used in small transparent animals (zebrafish, larval models). Technically in vivo and provides whole-brain fast activity imaging.
50. **Swept Confocally-Aligned Planar Excitation (SCAPE) Microscopy**  
High-speed volumetric neural imaging in freely moving animals.
51. **Structured-Light 3D Imaging of Cortical Hemodynamics**  
Used to map neural activity via intrinsic signals & hemodynamic changes.
52. **Mesoscopic Calcium Imaging (NOT miniscope)**  
Widefield mesoscopic  $\text{Ca}^{2+}$  imaging in vivo (distinct from fiber photometry).
53. **Adaptive Optics for In Vivo Neural Imaging**  
Corrects deep-tissue optical distortion; rapidly emerging technique.
54. **Oblique Plane Microscopy (OPM)**  
High-resolution, high-speed volumetric imaging for large-scale neural activity monitoring.
55. **Multifocal Two-Photon Microscopy**  
Simultaneous imaging of multiple planes for 3D functional imaging.
56. **Line-Scanning Temporal Focusing Microscopy**  
High-speed volumetric imaging with reduced out-of-focus excitation.
57. **Light Field Microscopy**  
Captures volumetric data in a single exposure for fast 3D neural activity imaging.
58. **Kilohertz Two-Photon Fluorescence Microscopy**  
Ultrafast scanning rates for capturing rapid neuronal dynamics in vivo.
59. **NIRE Cranial Window Method**  
Uses nanosheet-resin windows for large-scale, chronic high-resolution imaging in
60. **Volumetric Fluorescence Lifetime Imaging Microscopy (FLIM) for In Vivo Metabolic Readouts**  
High-speed volumetric FLIM approaches enabling in vivo mapping of metabolic state (NADH, FAD) and oxygen-consumption dynamics across populations of cells.
61. **[NEW] TIRF Microscopy In Vivo**  
Total internal reflection fluorescence microscopy adapted for superficial cortical imaging in live animals.
62. **[NEW] Random Access Microscopy**  
Acousto-optic deflector-based rapid laser positioning for imaging distributed neurons.
63. **[NEW] Reflectance Imaging**  
Measures intrinsic optical signals from cortical surface without exogenous labels.

64. **[NEW] Second Harmonic Generation (SHG) Microscopy**  
Label-free imaging of membrane potential and structural proteins in live tissue.
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## E. Optical Indicators / Novel Sensors

65. **Genetically Encoded Dopamine Indicators (GRAB-DA, dLight1)**  
Used widely in in vivo with fiber photometry and two-photon microscopy.
66. **Genetically Encoded Glutamate Indicators (IGluSnFR)**  
High temporal resolution; used to study excitatory transmission.
67. **Genetically Encoded Acetylcholine Indicators (GACH)**  
Maps cholinergic dynamics in vivo.
68. **Genetically Encoded cAMP/PKA/Second-Messenger Sensors**  
(e.g., Pink Flamindo, G-Flamp) reflect intracellular signaling during neural activity.
69. **Genetically Encoded Serotonin Sensors (GRAB5-HT)**  
Monitor serotonergic transmission in behaving animals.
70. **Genetically Encoded Norepinephrine Sensors (GRAB-NE)**  
Track noradrenergic activity during behavior and cognitive tasks.
71. **Fluorescent False Neurotransmitters (FFNs)**  
Visualize neurotransmitter release and recycling in vivo.
72. **Genetically Encoded Chloride Indicators (Cl-Sensor)**  
Monitor chloride dynamics relevant for inhibitory transmission.
73. **Genetically Encoded ATP Indicators (IATPSnFR)**  
Track cellular energy status and metabolic activity in neurons.
74. **Genetically Encoded Lactate Sensors**  
Monitor lactate shuttling and metabolic coupling between neurons and glia.
75. **Genetically Encoded Redox Indicators (roGFP)**  
Detect oxidative stress and redox-state changes during neural activity.
76. **Genetically Encoded Nitric Oxide Sensors (geNOps and related probes)**  
Fluorescent genetically encoded reporters for nitric oxide dynamics to monitor NO signaling in vivo during neural activity.
77. **[NEW] Genetically Encoded Potassium Indicators (GEPs)**  
Fluorescent sensors for monitoring potassium dynamics in extracellular space.
78. **[NEW] pHluorins (pH-sensitive GFPs)**  
pH-sensitive fluorescent proteins for tracking synaptic vesicle recycling.
79. **[NEW] SypHy**  
Synaptophysin-pHluorin fusion protein for imaging synaptic vesicle exocytosis.
80. **[NEW] GCamp Variants (GCamp6f, GCamp7f, GCamp8)**  
Successive generations of genetically encoded calcium indicators with improved kinetics and sensitivity.
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## F. Photoacoustic & Hybrid Techniques

81. **Voltage-Sensitive Photoacoustic Imaging**  
A new area combining voltage dyes with photoacoustics.
  82. **Nanodiamond Magnetometry in Vivo**  
Nitrogen-vacancy (NV) diamond sensors used for in vivo magnetic-field measurements of neuronal activity.
  83. **Multispectral Optoacoustic Tomography (MSOT)**  
Provides spectral unmixing of multiple chromophores for functional brain imaging.
  84. **Photoacoustic Computed Tomography (PACT)**  
Deep-tissue functional imaging with optical contrast and ultrasound resolution.
  85. **Functional Photoacoustic Microscopy (fPAM)**  
High-resolution imaging of hemodynamic responses to neural activity.
  86. **Photoacoustic Lifetime Imaging Microscopy (PALM)**  
Measures oxygen consumption and metabolic rates in brain tissue.
  87. **Microbubble-Enhanced Functional Ultrasound (Contrast-Enhanced fUS)**  
Use of intravascular microbubble contrast agents to boost sensitivity and spatial resolution of functional ultrasound hemodynamic measurements linked to neural activity.
  88. **[NEW] Photoacoustic Neurotransmitter Sensing**  
Molecular imaging of neurotransmitter release using photoacoustic contrast agents.
  89. **[NEW] Granger Causality Photoacoustic Imaging**  
Combines photoacoustic imaging with Granger causality analysis for functional connectivity mapping.
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## G. Neural Activity Through Blood Flow & Oxygenation

90. **Thermal Infrared Functional Imaging (ITIRI)**  
Detects activity-induced microvascular heating.
91. **Speckle-Modulated Optical Coherence Tomography (OCT)**  
OCT-based neuronal activity mapping (beyond standard laser speckle imaging).
92. **Doppler Optical Coherence Tomography (D-OCT)**  
For real-time blood-flow-linked neural-activity measurements.
93. **Visible Light Optical Coherence Tomography (vis-OCT)**  
Provides oximetry and flow measurements with higher resolution than NIR-OCT.
94. **Hyperspectral Imaging of Intrinsic Signals**  
Spectral unmixing of hemoglobin, cytochrome oxidase, and other chromophores.
95. **Time-Domain Near-Infrared Spectroscopy (TD-NIRS)**  
Offers depth-resolved hemodynamic monitoring with improved accuracy.
96. **Functional Diffuse Optical Tomography (fDOT)**  
3D reconstruction of brain activation through light scattering and absorption.
97. **In Vivo Electron Paramagnetic Resonance (EPR) Oximetry**  
Direct in vivo EPR/Electron Spin Resonance oximetry for quantitative tissue pO<sub>2</sub> mapping and dynamic oxygen-consumption measurements coupled to neural activity.

98. **[NEW] Laser Doppler Flowmetry**  
Continuous measurement of cerebral blood flow using laser Doppler shifts.
  99. **[NEW] Oxygen-15 Water PET ( $[^{15}\text{O}]\text{H}_2\text{O}$  PET)**  
Gold standard for quantitative cerebral blood flow measurement using positron emission tomography.
  100. **[NEW] Hydrogen Clearance CBF Measurement**  
Historical method using hydrogen electrodes to measure local cerebral blood flow.
  101. **[NEW] Autoradiographic CBF Measurement ( $[^{14}\text{C}]\text{iodoantipyrine}$ )**  
Ex vivo quantitative mapping of cerebral blood flow using radiotracers.
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## H. Behavioral + Neural Integrated Techniques

102. **Neuromorphic Cameras Linked With Neural Imaging**  
High-speed event-driven sensors capturing animal behavior synchronized with brain activity (not a brain technique per se, but part of modern in vivo pipelines).
  103. **Deep Label-Free Microscopy (DLFM)**  
Uses deep learning to extract neural activity from label-free imaging of scattering changes.
  104. **Acoustic Recording of Neural-Related Behavior**  
Ultrasonic vocalization recording synchronized with neural activity measurements.
  105. **Eye-Tracking Integrated Neural Recording**  
Combines pupil tracking with brain activity to study visual attention and processing.
  106. **Pose Estimation with Neural-Activity Synchronization**  
Uses AI-based body tracking (e.g., DeepLabCut) linked to real-time neural signals.
  107. **Real-Time Closed-Loop Neural Decoding & Stimulation Systems**  
Integrated pipelines that decode ongoing neural activity in real time and deliver contingent stimulation (optogenetic, electrical, ultrasonic) to probe causality during behavior.
  108. **[NEW] Whisker Tracking with Neural Recording**  
High-speed videography of whisker movements synchronized with neural data.
  109. **[NEW] Operant Conditioning Chambers with Neural Interfaces**  
Behavioral boxes integrated with neural recording/stimulation for learning studies.
  110. **[NEW] Sleep-Wake Monitoring with EEG/EMG**  
Polysomnography combined with neural activity measurements across sleep stages.
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## I. Interference / Modulation Techniques

111. **Focused Ultrasound Blood–Brain Barrier Opening (FUS-BBBO)**  
Used in vivo to modulate circuits or allow entry of neuromodulators.

- 112. **Temporal Interference Stimulation (TI Stimulation)**  
Non-invasive deep-brain electromagnetic stimulation using intersecting high-frequency currents.
  - 113. **Transcranial Random Noise Stimulation (RNS)**  
Another electrical non-invasive modulation technique widely used.
  - 114. **Photothermal Neuromodulation (non-genetic)**  
Uses nanoparticles or infrared light to activate neurons.
  - 115. **Infrared Neural Stimulation (INS)**  
Pulsed IR light drives neural activity—distinct from optogenetics.
  - 116. **Scanning Ultrasound Neuromodulation (SUN)**  
Focused ultrasound for precise spatiotemporal neural control.
  - 117. **Optoacoustic Neuromodulation**  
Uses laser-generated ultrasound for deep-brain stimulation.
  - 118. **Ion-CeMST (Ion Current–Controlled Microfluidic Stimulation)**  
Microfluidic-based chemical stimulation with spatiotemporal precision.
  - 119. **Transcranial Photobiomodulation (tPBM)**  
Low-level near-infrared light to modulate brain metabolism and activity.
  - 120. **Vagus Nerve Stimulation (VNS)**  
Electrical stimulation of vagus nerve to indirectly influence brain circuits.
  - 121. **Deep Transcranial Magnetic Stimulation (dTMS)**  
Uses H-coil for deeper penetration than standard TMS.
  - 122. **Closed-Loop Responsive Neurostimulation (RNS) for Research**  
Implantable or external systems that detect electrophysiological biomarkers and
  - 123. **[NEW] Chemical-Genetic Actuation (PSAM/PSEM)**  
Pharmacologically selective actuator modules for remote neural control.
  - 124. **[NEW] Cortical Cooling**  
Focal cooling for reversible neural inactivation to study functional localization.
  - 125. **[NEW] Lidocaine Inactivation**  
Local pharmacological blockade of neural activity for connectivity mapping.
  - 126. **[NEW] Muscimol Inactivation**  
GABAA receptor agonist for reversible cortical silencing in behavioral studies.
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## J. Emerging & Frontier Approaches

- 127. **Bioluminescent Voltage Imaging (e.g., LOTUS-V)**  
No excitation light; extremely low phototoxicity for in vivo activity imaging.
- 128. **Upconversion Nanoparticle-Based Neural Imaging**  
Allows deeper brain optical readout using NIR-to-visible conversion.
- 129. **Magnetothermal Neural Recording & Readout**  
Not just thermogenetic stimulation—actual readout emerging via nanomaterials.
- 130. **Molecular fMRI (m-fMRI)**  
Probes coupling specific cellular signaling events to MRI contrast.
- 131. **Functional Ultrasound Localization Microscopy (ULM-fUS)**  
Super-resolution vascular mapping during activity.

132. **"Neuromodulation via Magnetic Nanodiscs"**  
A newer mechanogenetic-like frontier method.
133. **Quantum Diamond Microscopy**  
Uses NV centers for magnetic imaging of neural activity at nanoscale.
134. **X-ray-Induced Acoustic Computed Tomography (XACT)**  
Combines X-ray absorption with ultrasound detection for functional imaging.
135. **Magnetic Resonance Spectroscopic Imaging (MRSI)**  
Spatially resolved spectroscopy for mapping neurotransmitter distributions.
136. **Neutron Stimulated Emission Computed Tomography (NSECT)**  
Emerging nuclear technique for elemental mapping of neural tissue.
137. **Holographic Optogenetic Stimulation**  
Uses holography for multi-site optical neural control and readout.
138. **Nanowire Intracellular Recordings**  
Nanoscale wires for minimally invasive intracellular potential measurements.
139. **AI-Augmented Functional Connectivity Analysis**  
Machine-learning-enhanced mapping of dynamic brain networks from imaging data.
140. **Cryogenic Electron Microscopy for In Vivo Snapshots**  
Adapted for rapid freezing and imaging of activity states (though borderline in vivo).
141. **In Vivo Quantum Diamond Scalp Magnetometry (NV-MEG)**  
Scalp-mounted or near-scalp arrays of diamond NV sensors for high-spatial-resolution magnetic field mapping of population neural currents, bridging nanoscale NV sensing advances with whole-head MEG-style recordings.
142. **[NEW] CLARITY with In Vivo Applications**  
Tissue transformation for post-mortem structural mapping of functionally identified circuits.
143. **[NEW] Expansion Microscopy In Vivo**  
Physical tissue expansion for super-resolution imaging of activated circuits.
144. **[NEW] Magnetic Resonance Phased Array Microscopy**  
Ultra-high field MRI with phased array coils for microscopic resolution in live animals.
145. **[NEW] X-ray Optogenetics**  
Combining X-ray stimulation with optogenetic actuators for deep brain modulation.
146. **[NEW] Neutron Scattering Tomography**  
Emerging technique for mapping light element distributions in neural tissue.
147. **[NEW] Diamond Quantum Sensing of Neural Magnetic Fields**  
NV center magnetometry for direct detection of action potentials and synaptic currents.