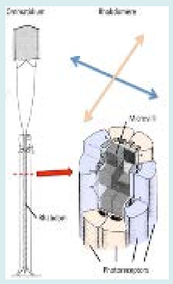
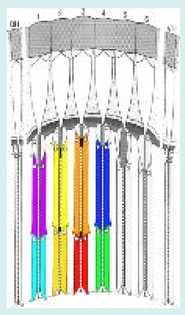
Polarization Focal Plane Sensing with Plasmonic Nanostructures for Functional Neural Imaging

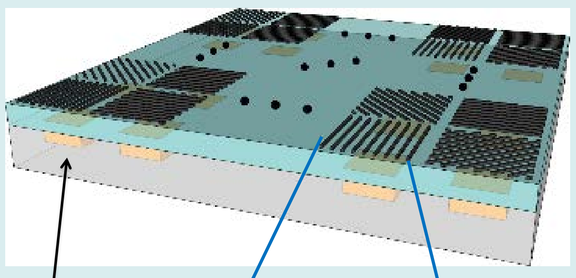
Viktor Gruev and Barani Raman, Washington University in St. Louis

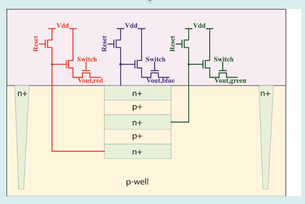
Department of Computer Science and Engineering, Department of Biomedical Engineering

Bio-inspired Circuits and Optics: Spectral-Polarization Imaging Sensor

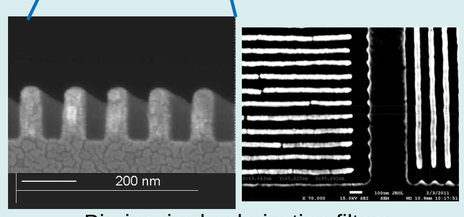






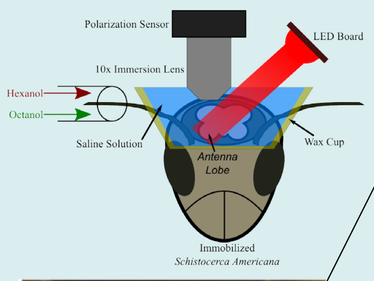


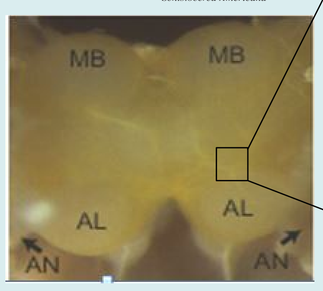
Bio-inspired spectral imager

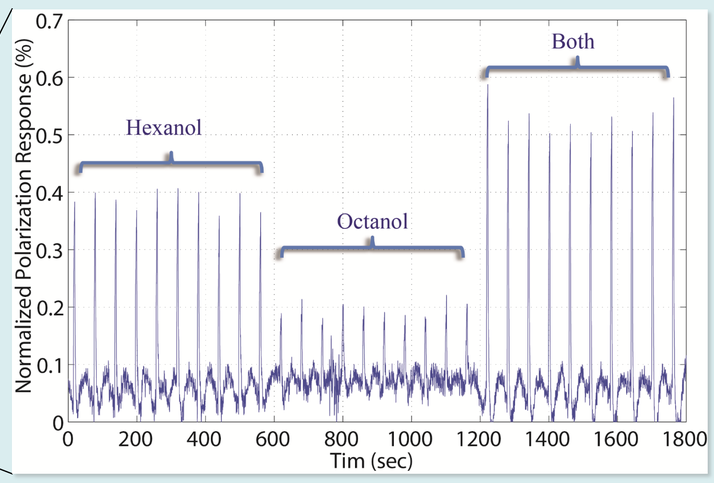


Bio-inspired polarization filters

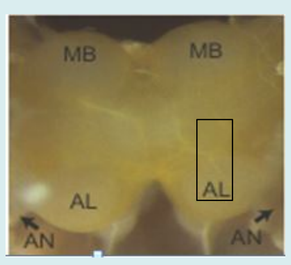
Preliminary data: Polarization based functional neural imaging

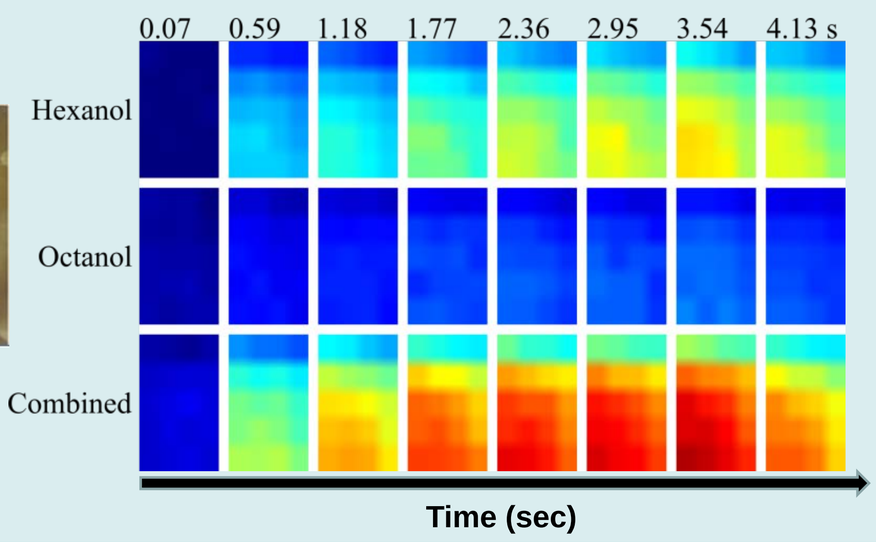




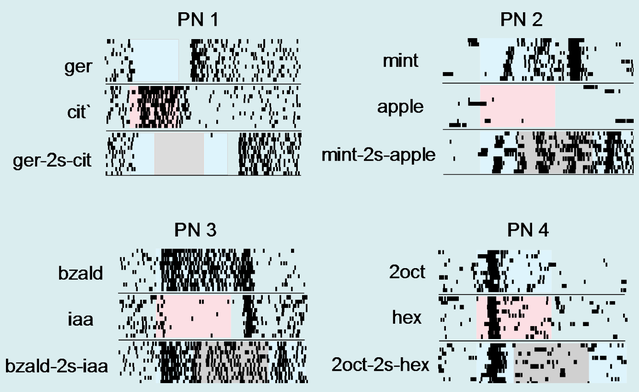


Preliminary data: Polarization based functional neural imaging





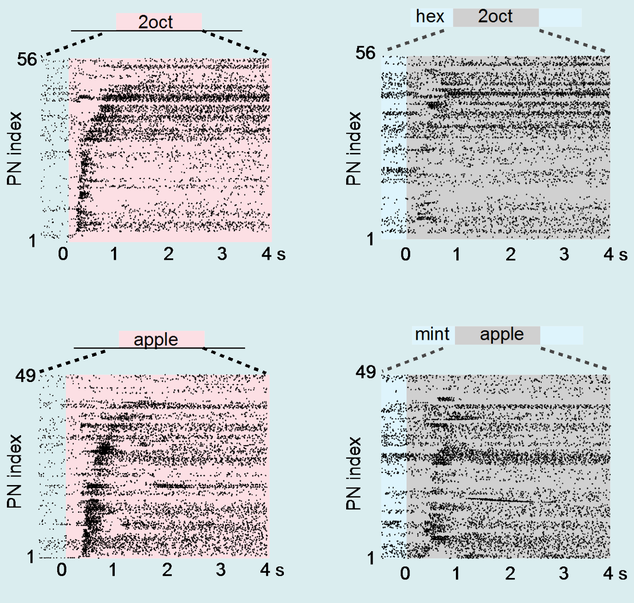
Olfactory computations: sensory invariance



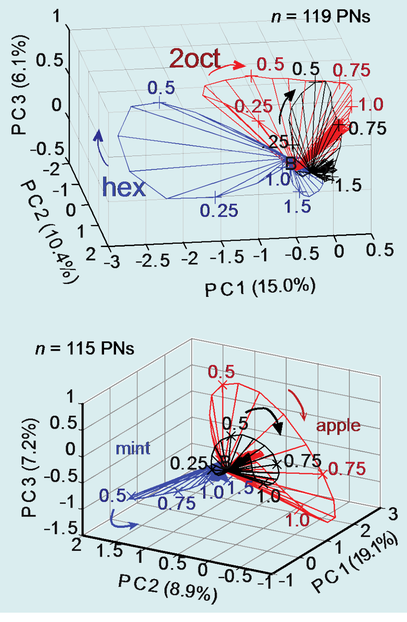
- Responses of Individual neurons in the insect antennal lobe (signal processing center analogous to the vertebrate olfactory bulb) varies with stimulus history.
- How then is sensory invariance maintained under varying conditions

- We find that the population neural responses can robustly encode for stimulus identity independent of background conditions.

Ensemble activity - raw resposes

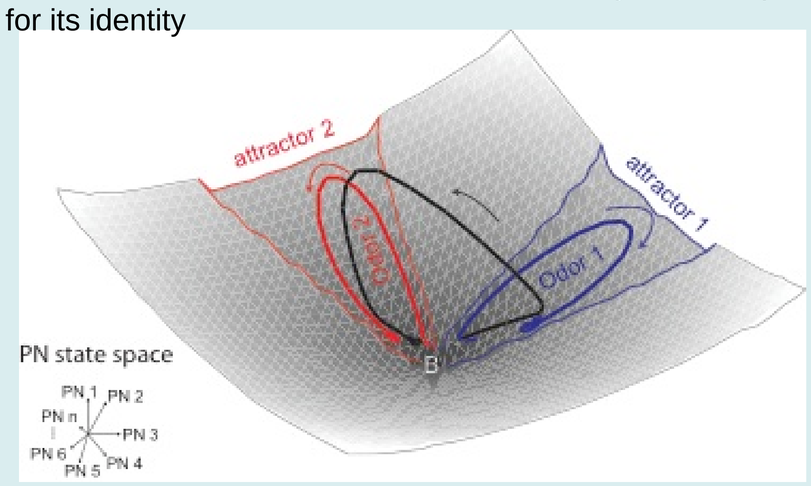


Response trajectory analysis

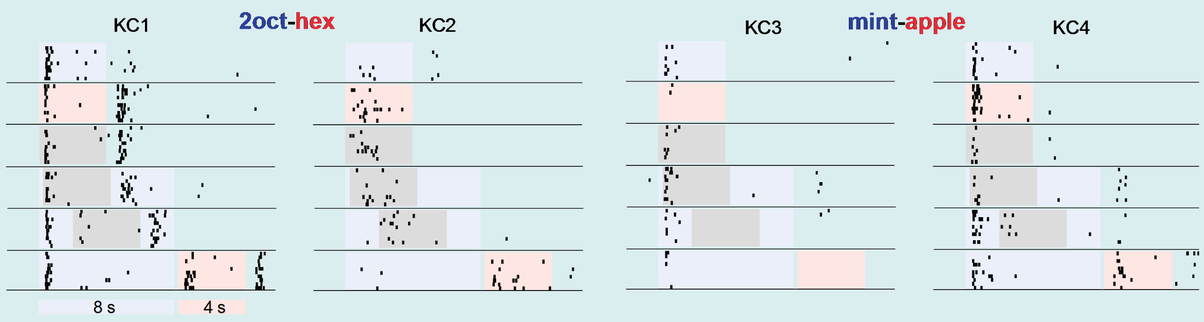


Attractor model for neural encoding

Our preliminary results reveal an interesting approach to neural computation: odorant evoke only certain combinations of ensemble neural activity: an ‘subspace’ or an ‘attractor’ that encodes for its identity



Responses in the memory and learning centers that interpret the ensemble activity from antennal lobe are sparse and consistent with the proposed ‘attractor model’.



The new optical recording method will provide sufficient spatial and temporal resolution to record simultaneously from both encoding and decoding centers and allow us to reveal fundamental olfactory information processing approaches.

Research Questions:

1.Can we validate the polarization contrast imaging and compared it to electrophysiology?

2. Can we increase the polarization sensitively of the polarization device by incorporating plasmonic nanowire filters?

3. Since we can image large population of in vivo neurons simultaneously, can we study spatial and temporal coding of information in the olfactory system?

4. How are important pattern recognition problems such as sensory invariance, gain control, contrast enhancement, mixture segmentation solved in a relatively simple olfactory system

5. What are the rules that govern how ensemble neural activity is translated to behavior?

References:

1. V. Gruev, R. Perkins, and T. York, "CCD polarization imaging sensor with aluminum nanowire optical filters," *Optics Express,* vol. 18, pp. 19087-19094, Aug 30 2010.
2. V. Gruev, "Fabrication of a dual-layer aluminum nanowires polarization filter array," *Optics Express,* vol. 19, pp. 24361-24369, Nov 21 2011.
3. M. Kulkarni and V. Gruev, "Integrated spectral-polarization imaging sensor with aluminum nanowire polarization filters," *Optics Express,* vol. 20, pp. 22997-23012, 2012.
4. S. Powell and V. Gruev, "Calibration methods for division-of-focal-plane polarimeters," *Optics Express*, vol. 21, pp. 21040-21056, 2013.
5. E. Gilboa, J. Cunningham, A. Nehorai and V. Gruev, “Image interpolation and denoising for division of focal plane sensors using Gaussian Processes,” *Optics Express*, vol. 22, Issue 12, pp. 15277-15291, 2014.
6. G. Calabrese, P. Brady, V. Gruev, and M. Cumming, "Dynamic Polarization Signaling in Swordtails Alters Female Mate Preference," to appear in Proceedings of National Academy, 2014.
7. D. Saha, K. Leong, C. Li, S. Peterson, G. Siegel and B. Raman, “A spatiotemporal coding mechanism for background-invariant odor recognition” Nature Neuroscience, vol. 16, pp. 1830-1839, 2013.