**Questions to be discussed by each group:**

*For Thursday’s breakout discussions*

What are the important opportunities, outstanding questions, scientific challenges?

What do heterostructures, films, bottoms-up growth techniques uniquely offer?

Are there competing theoretical explanations and how can experiments adjudicate?

What advances can we realize if we gained insight; what’s at stake, what’s the impact?

Which questions require integration of synthesis, characterization and theory to solve?

Which questions require a large multidisciplinary effort to solve?

*For Friday’s cross-cutting discussions*

What are the synthesis, characterization and theory challenges?

Which tools are needed that don’t exist and must be developed?

**Theme: Exploit topology to produce novel states of quantum matter**

*Example Topics*

How can heterostructures be used to create interesting topology?

How can topology manipulate quantum matter, e.g., spin, orbital, phonon, superconductivity?

Specific physics to consider:

* Spin texture as in quantum spin hall effect, Berry phase, skrymions, hedgehogs
* Insulators (Chern, topological),
* Fermions (Weyl, Majorana),
* Metals (Weyl)
* Axion electrodynamics, design experiments that test perturbation to Maxwell’s equations

*Reading*

<http://physics.aps.org/articles/v5/28>

<http://physics.aps.org/articles/v1/36>

<http://journals.aps.org/prb/abstract/10.1103/PhysRevB.78.195424> pages 21-22!

<https://physics.aps.org/articles/v1/6>

**Theme: Exploit disorder to produce novel states of quantum matter**

*Example Topics*

How can disorder, inhomogeneity, spatial confinement manipulate quantum condensed matter, or select a preferred ground state (order by disorder)?

Or, the converse, how do inhomogenous states emerge from homogenous systems?

Specific physics to consider:

* Use disorder to break time, space, gauge symmetry
* Produce environments for quantum fluctuations, e.g., quantum spin ice, quantum spin liquids, compositionally graded materials, pyrochlores, metal organic frameworks
* How do we manipulate multiple order parameters, strain, polarization, magnetization, toroidic in mesoscale materials that inhabit quantum and classical physics?

*Reading*

<https://physics.aps.org/articles/v2/1>

<https://www.sciencedaily.com/releases/2015/07/150731070449.htm>

<http://journals.aps.org/prl/pdf/10.1103/PhysRevLett.62.2056> (order by disorder)

**Theme: Manipulate quantum coherence**

*Example Topics*

How can we control coherence of wave functions, including electrons, spins, orbital, phonons, for example with heterostructures?

Specific physics to consider:

* Quantum entanglement
* Separation of spin, orbit, and charge to form quasiparticles.
* Thermal transport; transition from incoherent to coherent phonon scattering.
* Produce and control solitons of wave functions, e.g., phonons, spins, superconductivity
* Proximity effects, penetration of superconducting wave function into magnetic order and vice versa. Can a working definition of “proximity effects” be formulated?
* Electrostatic gating to control quantum spin liquids
* Interaction between superconducting wave function and topology

*Reading*

<https://physics.aps.org/articles/pdf/10.1103/Physics.8.112>

<http://www.nature.com/articles/srep23336?WT.feed_name=subjects_electronic-and-spintronic-devices>

**Theme: Produce far from equilibrium states of matter**

*Example Topics*

Production of states of matter far from equilibrium encompasses two issues. First, what opportunities do we have to synthesize novel materials under conditions far from equilibrium (this touches on the “in situ synthesis and characterization” BRN. Second, after a material is made can it be driven, e.g., in situ or in operando, far away from equilibrium and how does the system respond?

Specific physics to consider:

* Opportunities to create new (nanoscale or mesoscale) matter with bottoms-up synthesis that simply cannot be achieved with bulk synthesis.
* How do we control of growth of interfaces, disorder?
* What forms of excitation/pumping are available to drive matter from equilibrium and amenable (or advantageous) to heterostructures?
* Driven new states of matter, e.g., Floquet physics, Floquet topological insulators
* Non thermal electron (or other quasiparticle) energy distributions, using pump-probe approaches or specifically designed non equilibrium quasiparticle transport experiments.
* Exploiting structural distortions that couple to optic modes, e.g., tilting octahedrons using optic pumping.
* Magnetic distortions that couple to electromagnetic radiation, e.g., FM, AFM or nuclear polarization, can be explored with magnetic resonance.
* Spin torque, coupling across interfaces, spin orbit coupling…
* Optic and magnetic resonance techniques to selectively excite modes, e.g., ones at an interface vs. bulk (environment selective labeling).
* Drive coherent excitations to create transient response/emergent properties.
* Valleyronics

*Reading*

<https://physics.aps.org/articles/v6/13>

<http://www.nature.com/nmat/journal/v11/n1/full/nmat3205.html>

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| <http://dx.di.org/10.1002/pssr.201206451> |
| <http://www.nature.com/articles/natrevmats201655> |
| <http://www.nature.com/nature/journal/v330/n6147/pdf/330418a0.pdf> |