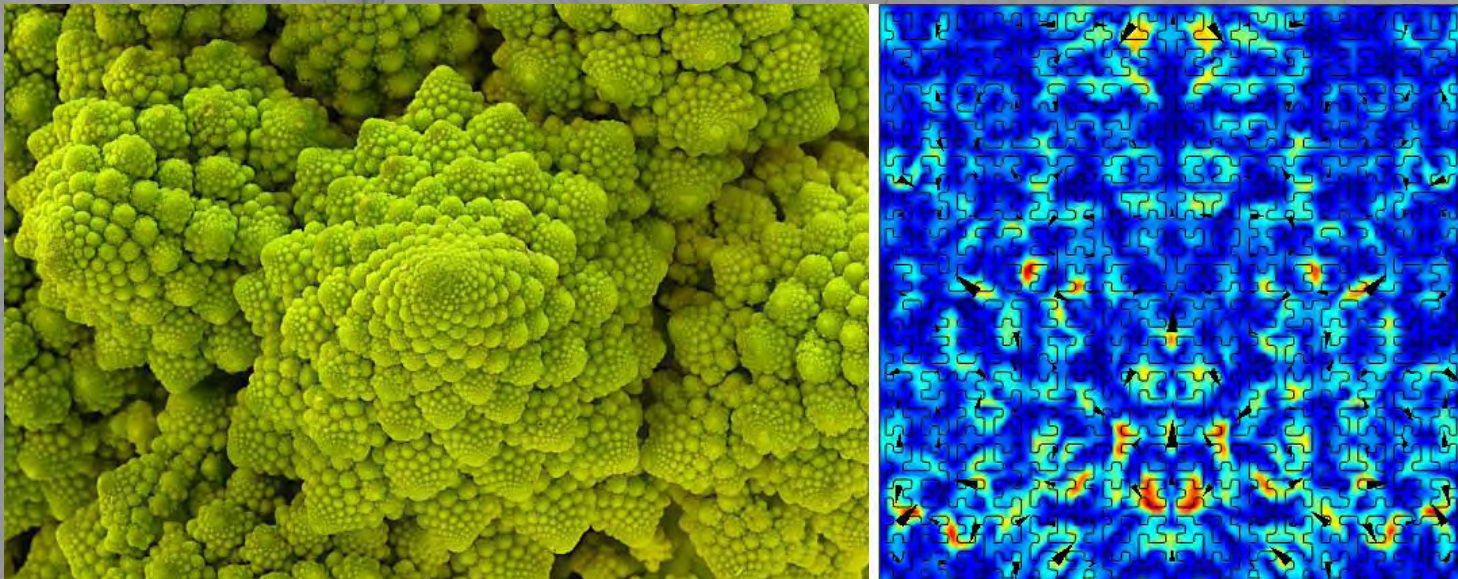


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Designing a Smart Skin with Fractal Geometry



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Nature's Beauty

- **What is fractal?**
 - A fractal is an object that has the same degree of complexity on different length scale

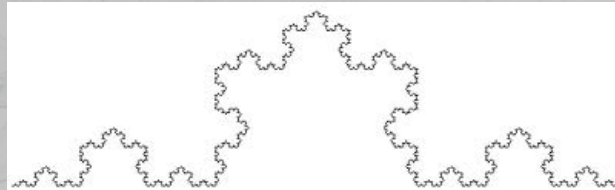


Why fractal

- Allows for more compact designed antenna
 - Their lower resonant frequency
- Nonlinear behavior of fractal aggregates
 - Lack of long range order yet high connectivity,
 - localized electric field on the fractal cluster → leads to huge field enhancement
- Possess multiband EM responses covering a broad frequency
 - Due to self-similarity
- Smart Skin

General Framework

- Identifies the fundamental mechanism for spectral opening in metamaterials:
 - avoided crossing
 - happened between eigenmodes with the same symmetry wrt relevant k vectors.
- Tested on well studied systems, also applicable for fractal system
- Symmetry of Fractals
 - Deterministic
 - Non-deterministic
 - The correlation function a valuable approach to quantitative describe the disordered system

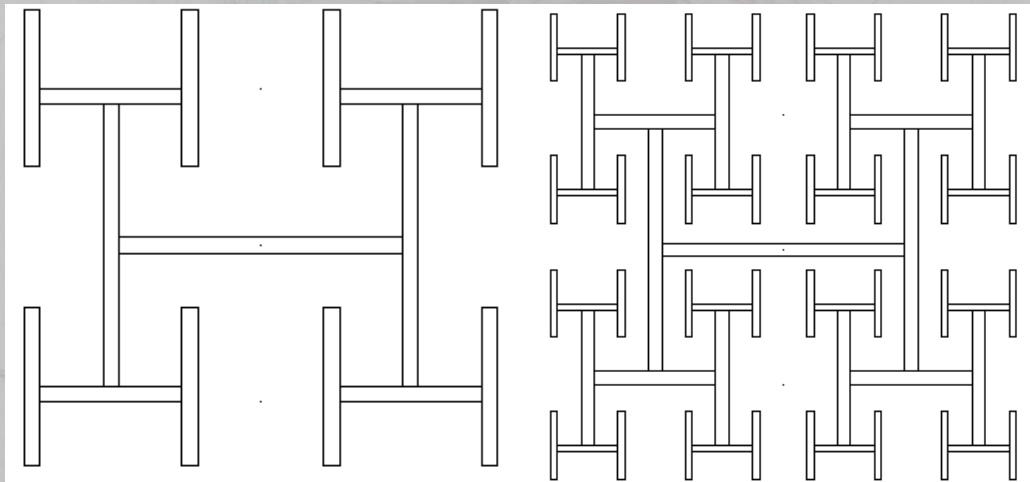


General Methodology

- Generate the fractal geometry
- Define the physics
 - Connected phase is usually matrix, and the other scatter phase
 - Periodic boundary condition
- Linked to Matlab to calculate dispersion curve
 - Usually for different matrix material constants
 - Other parameters has also been studied
- Investigate the eigenmode
 - Looking at the dispersion curve.

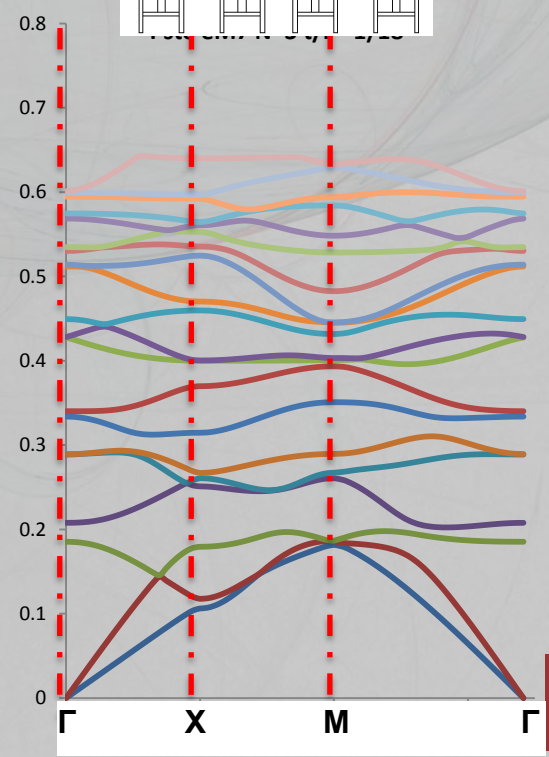
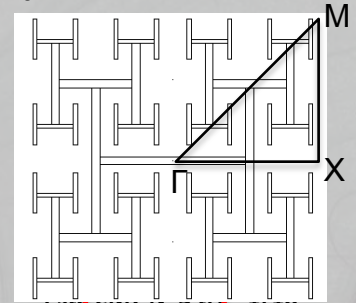
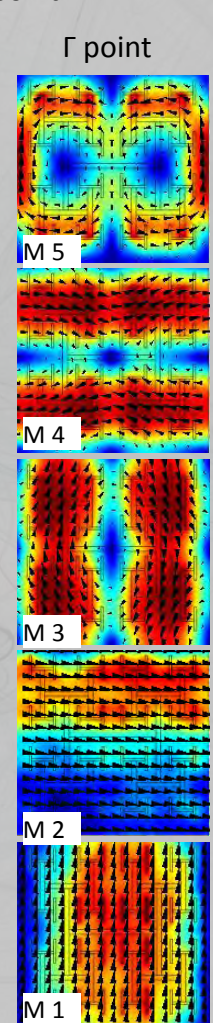
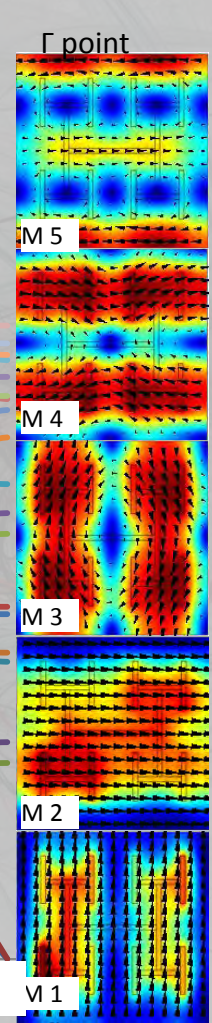
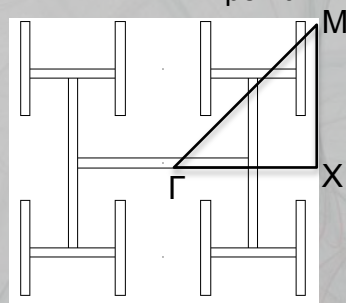
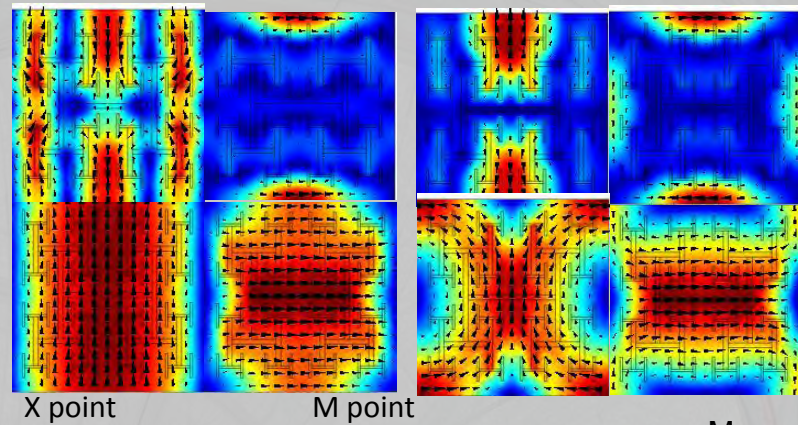
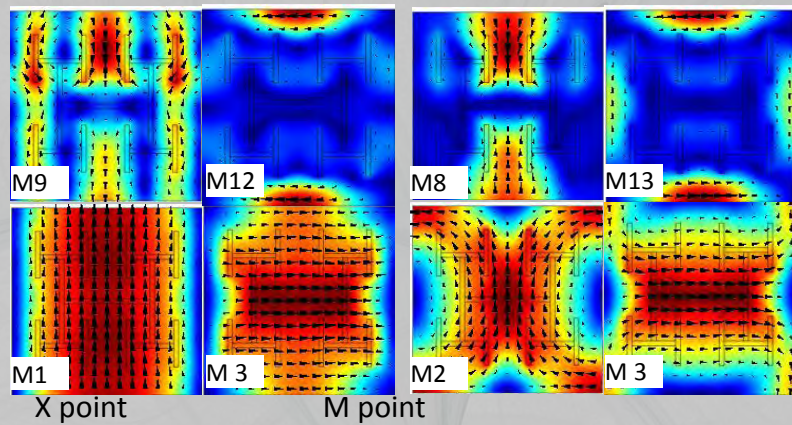
Fractal: deterministic Fractal

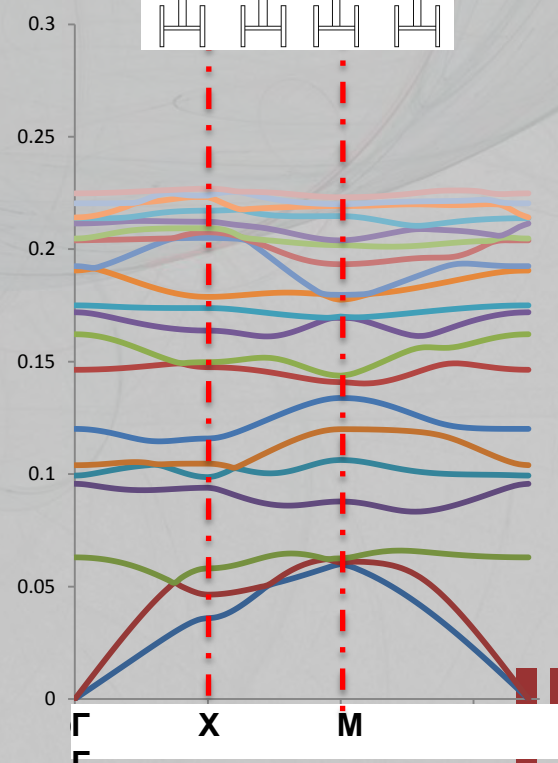
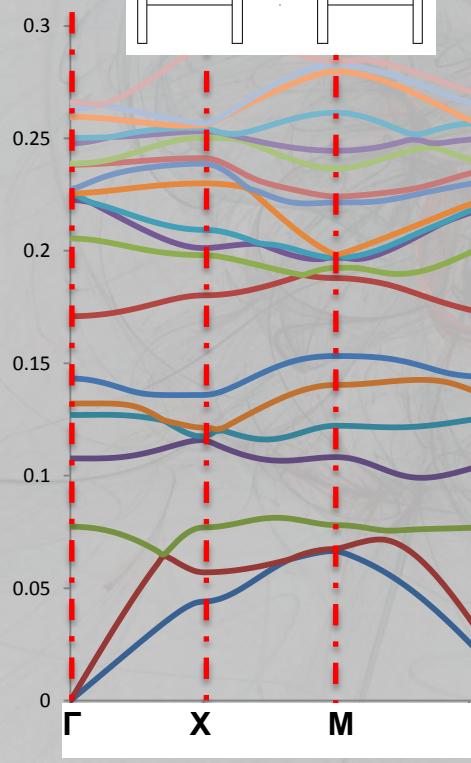
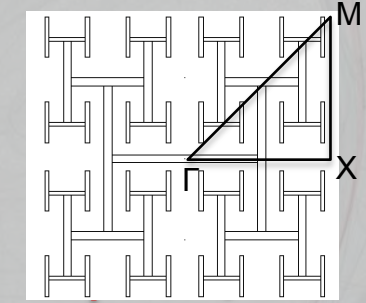
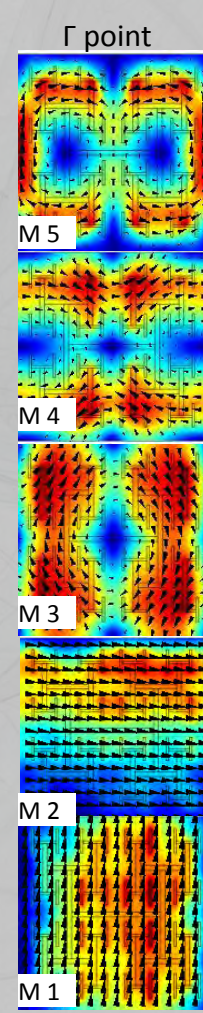
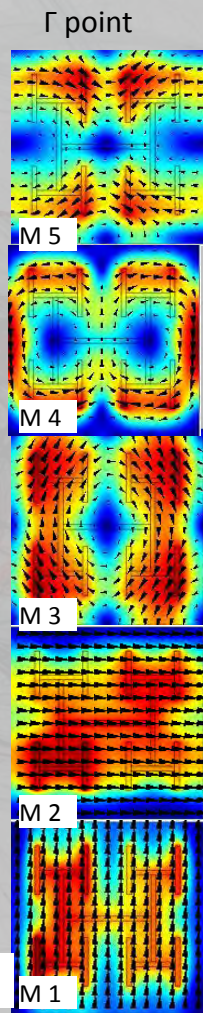
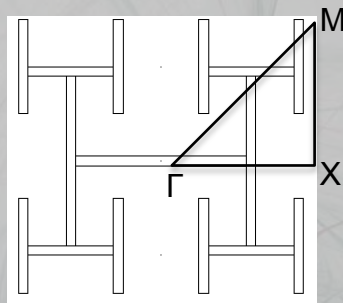
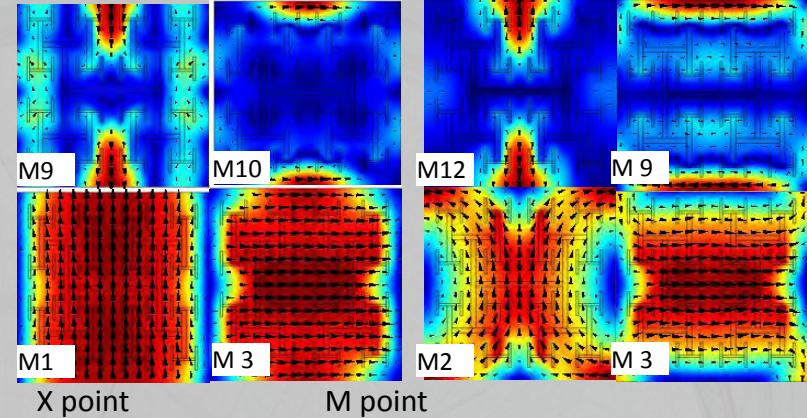
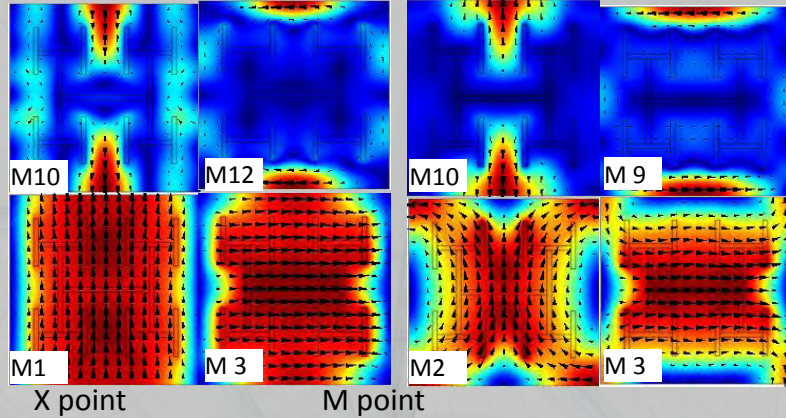
- H pattern
 - Been studied for electronic metamaterials due to its connectivity
 - Generation rule:
 - scale down the H pattern and then put them on each tip the of vertical H arm as the next level



	Scatter	Matrix
Young's Modulus Pa	40.8E9	4.35E7 or 4.35E6
Poisson Ratio	0.25	0.25
Density	11600	1180

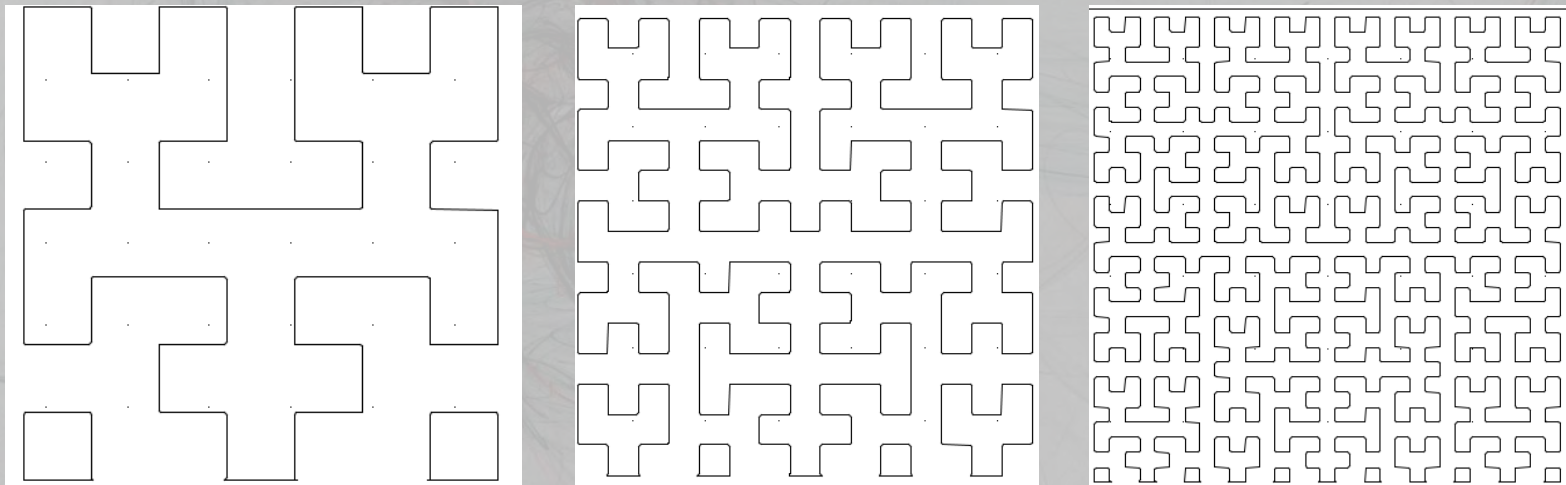
H pattern generated at different iteration numbers



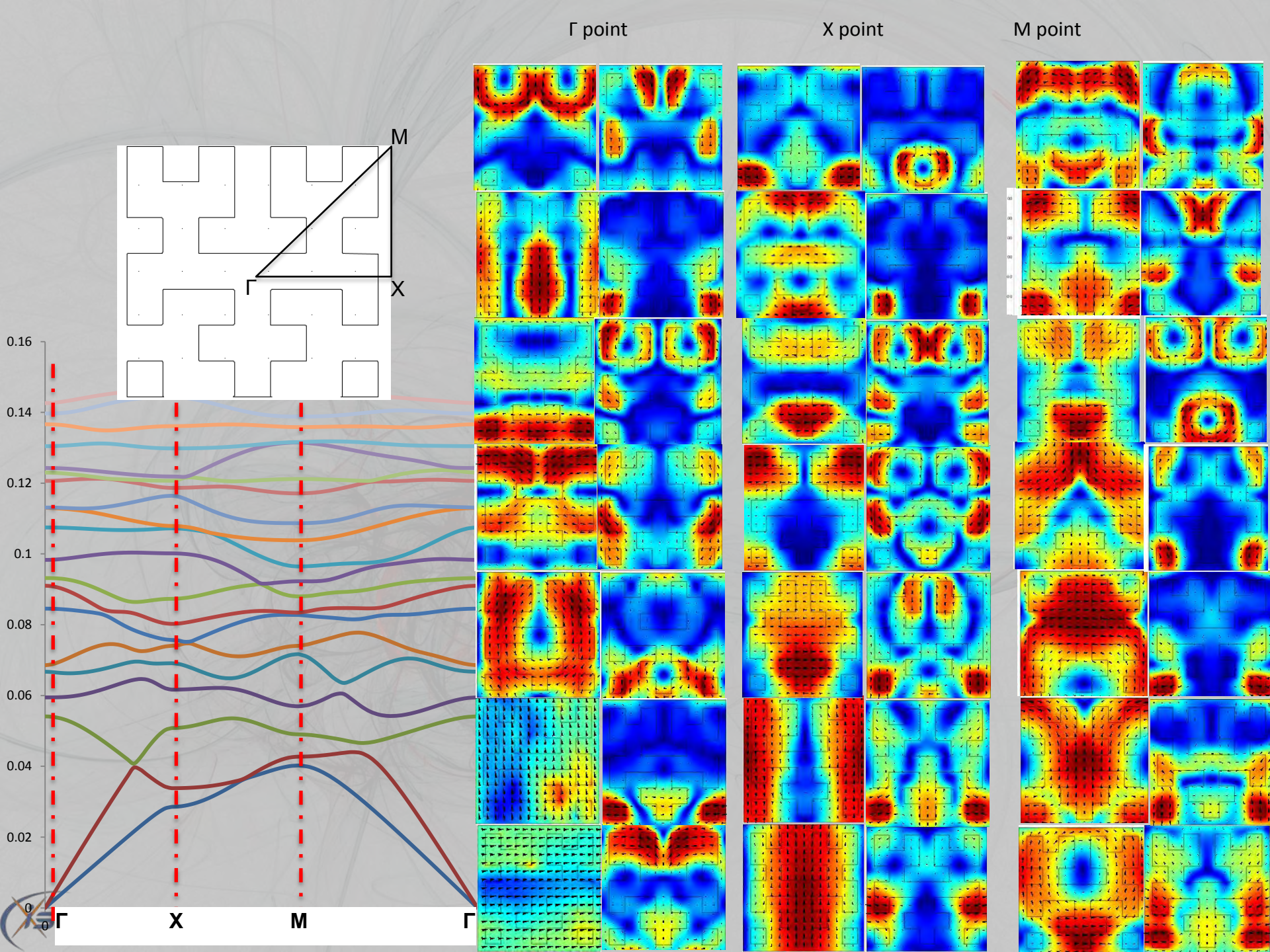


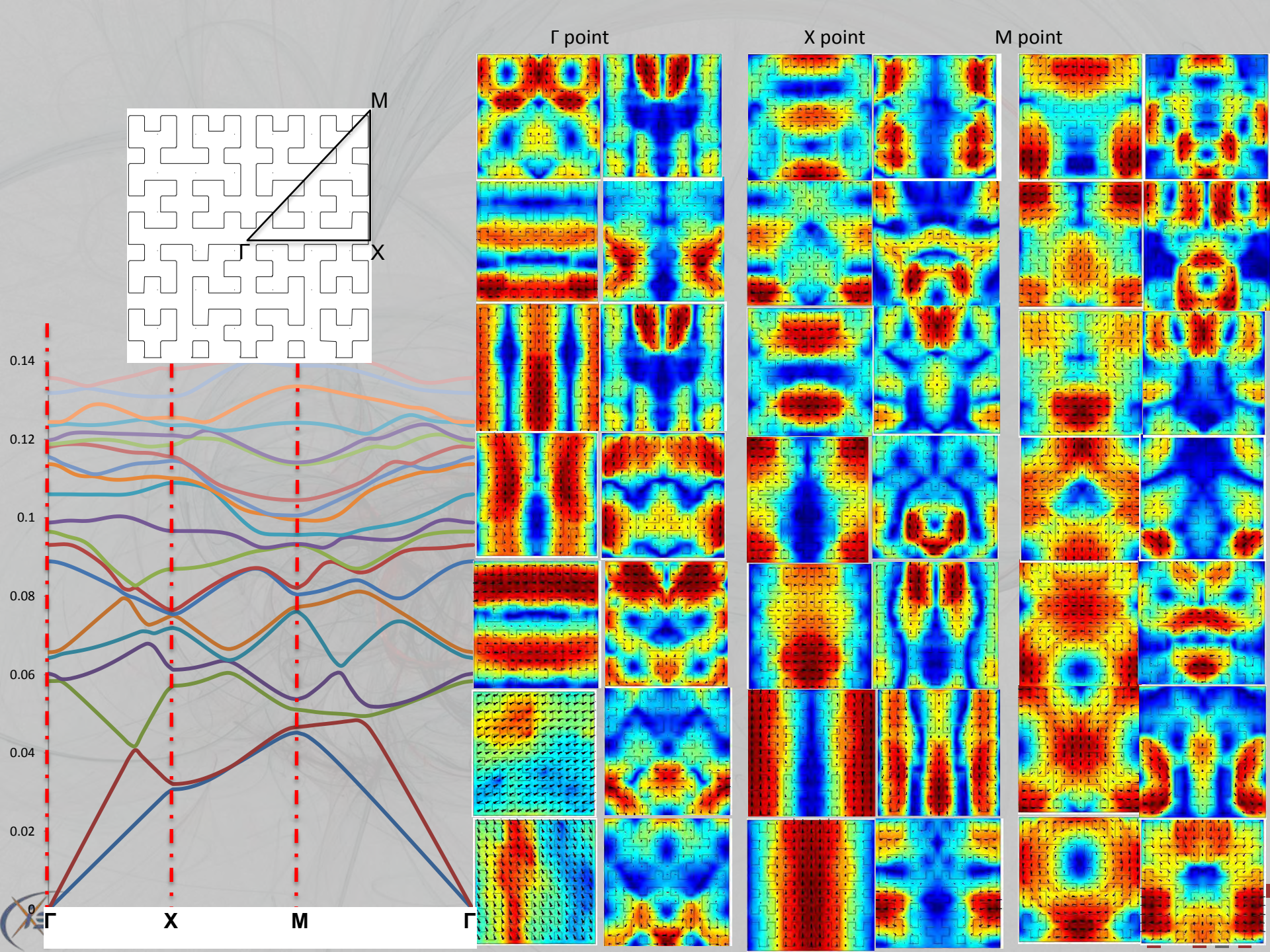
Deterministic Fractal

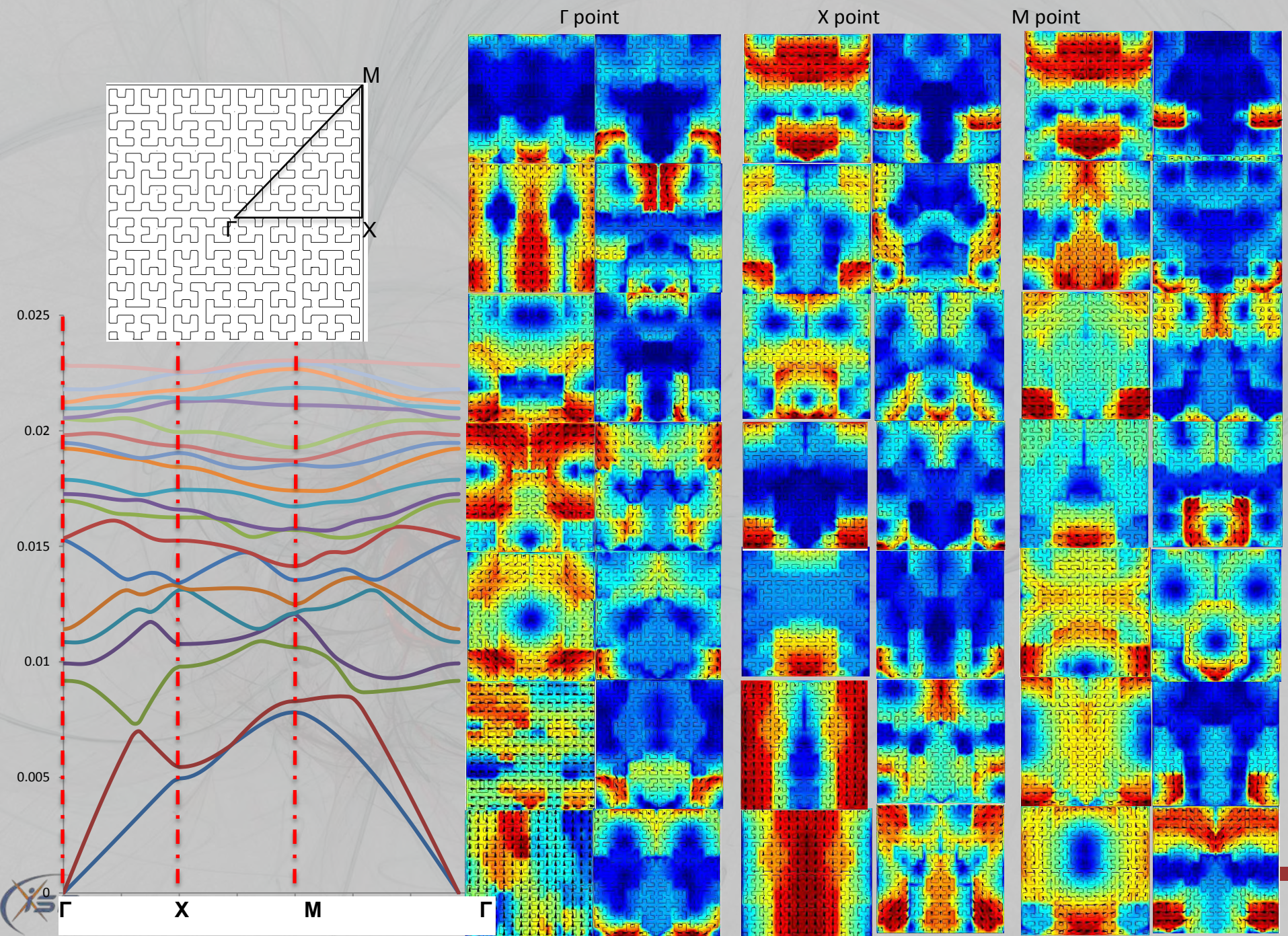
- Hilbert Curve
 - One of the space filling curves
 - Generation rule:
 - Start with a square and divide them into four squares and connect the centers while leave one side open
 - Divide the square into four square again and again



Binary system bounded by Hilbert Curve with different level of iteration

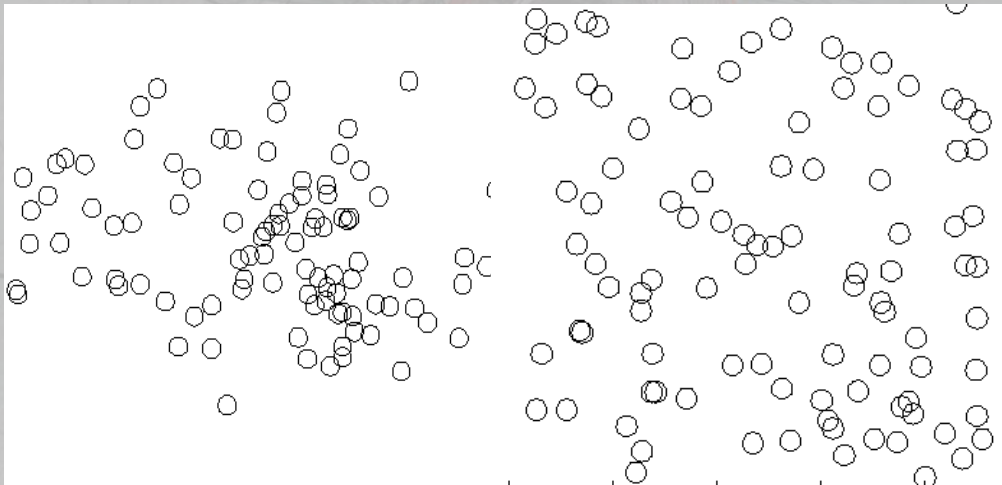


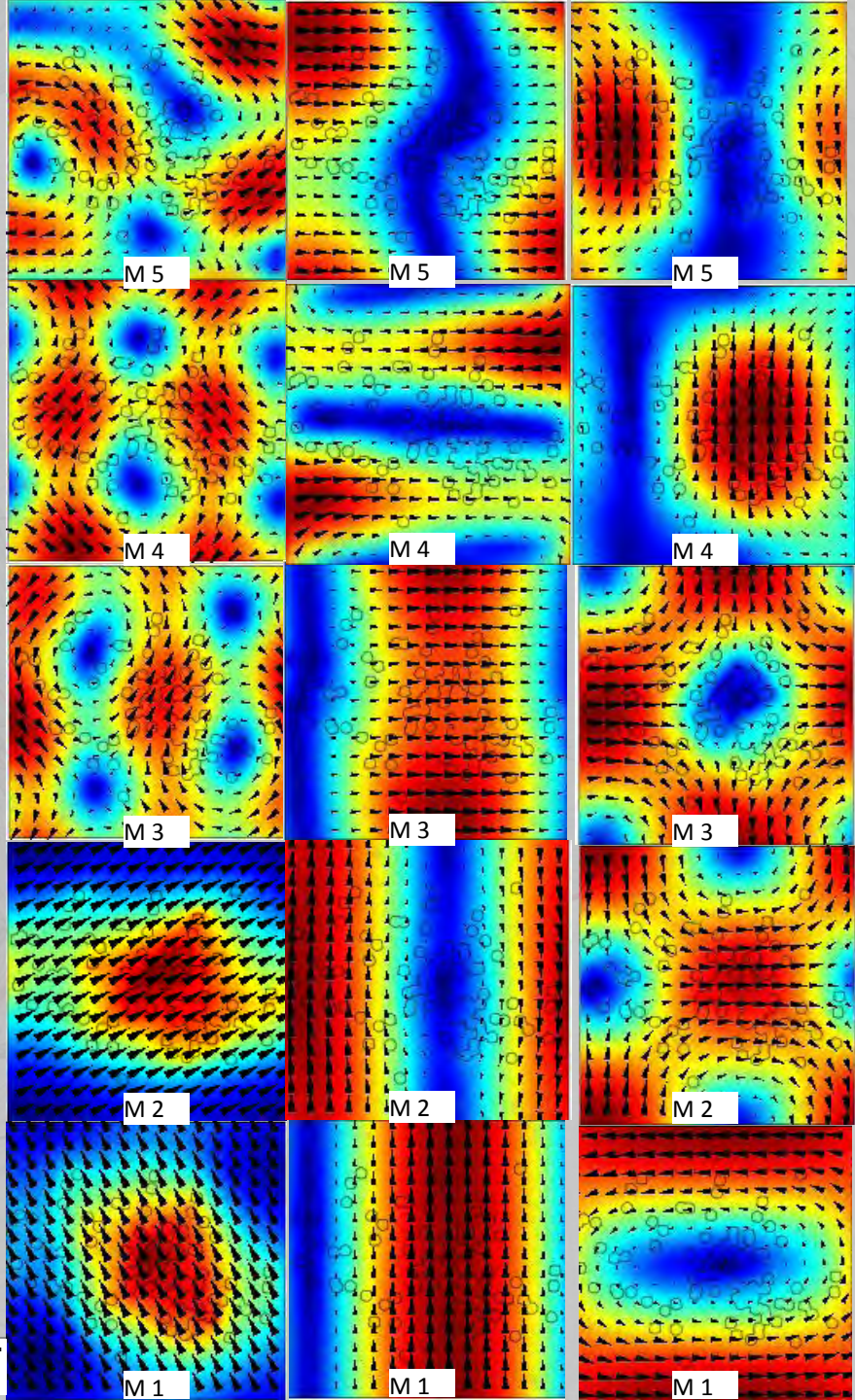
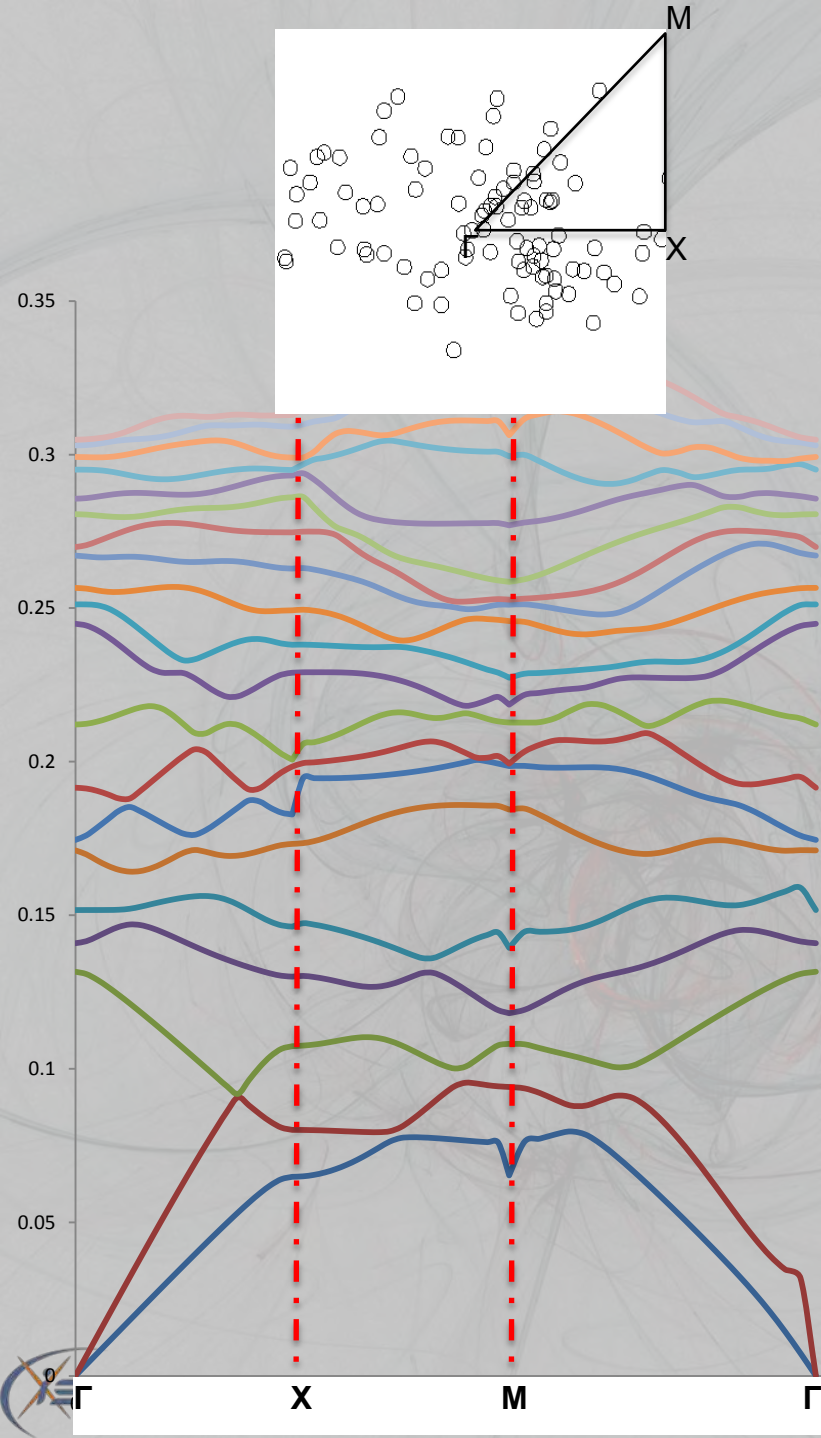


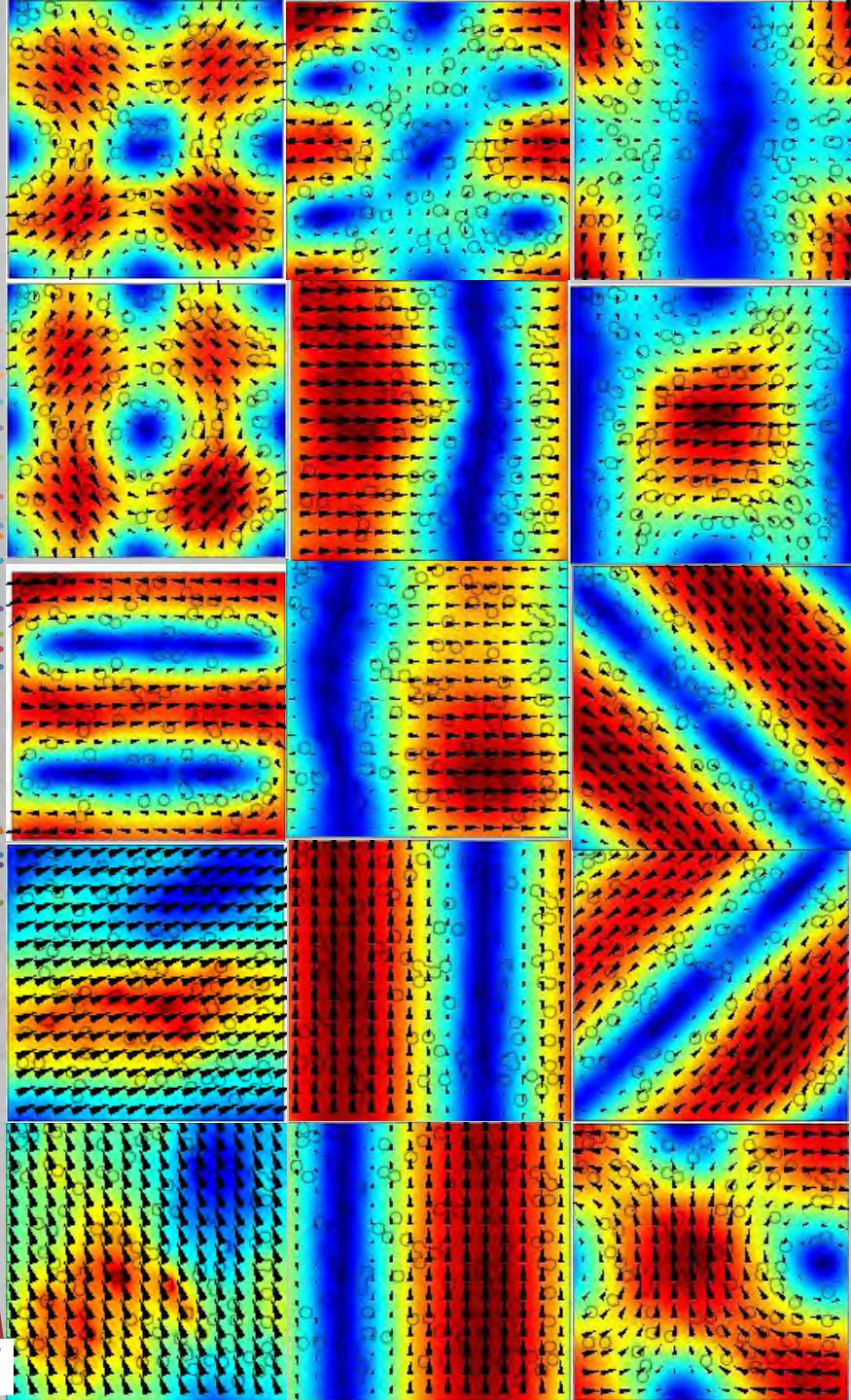
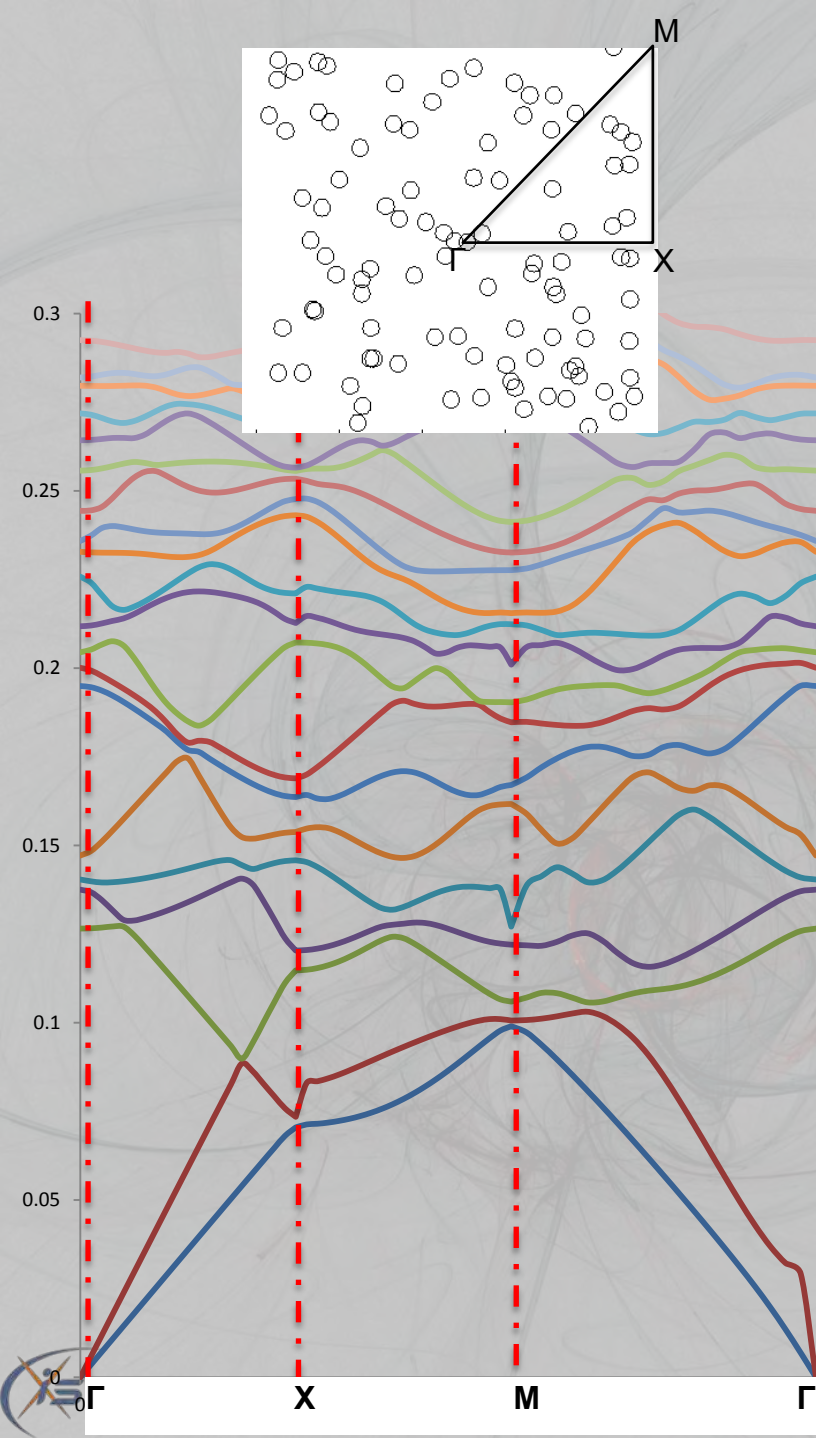


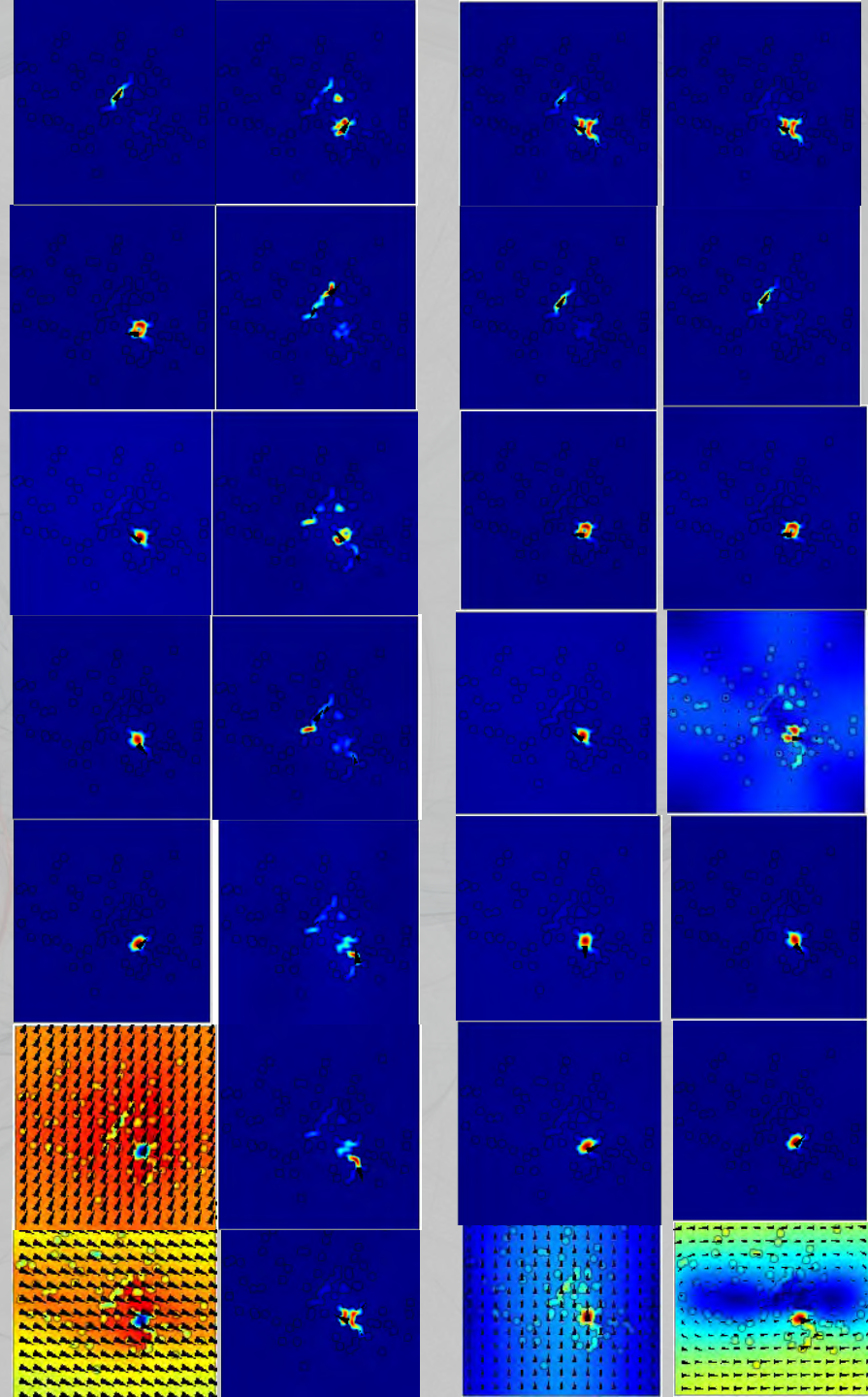
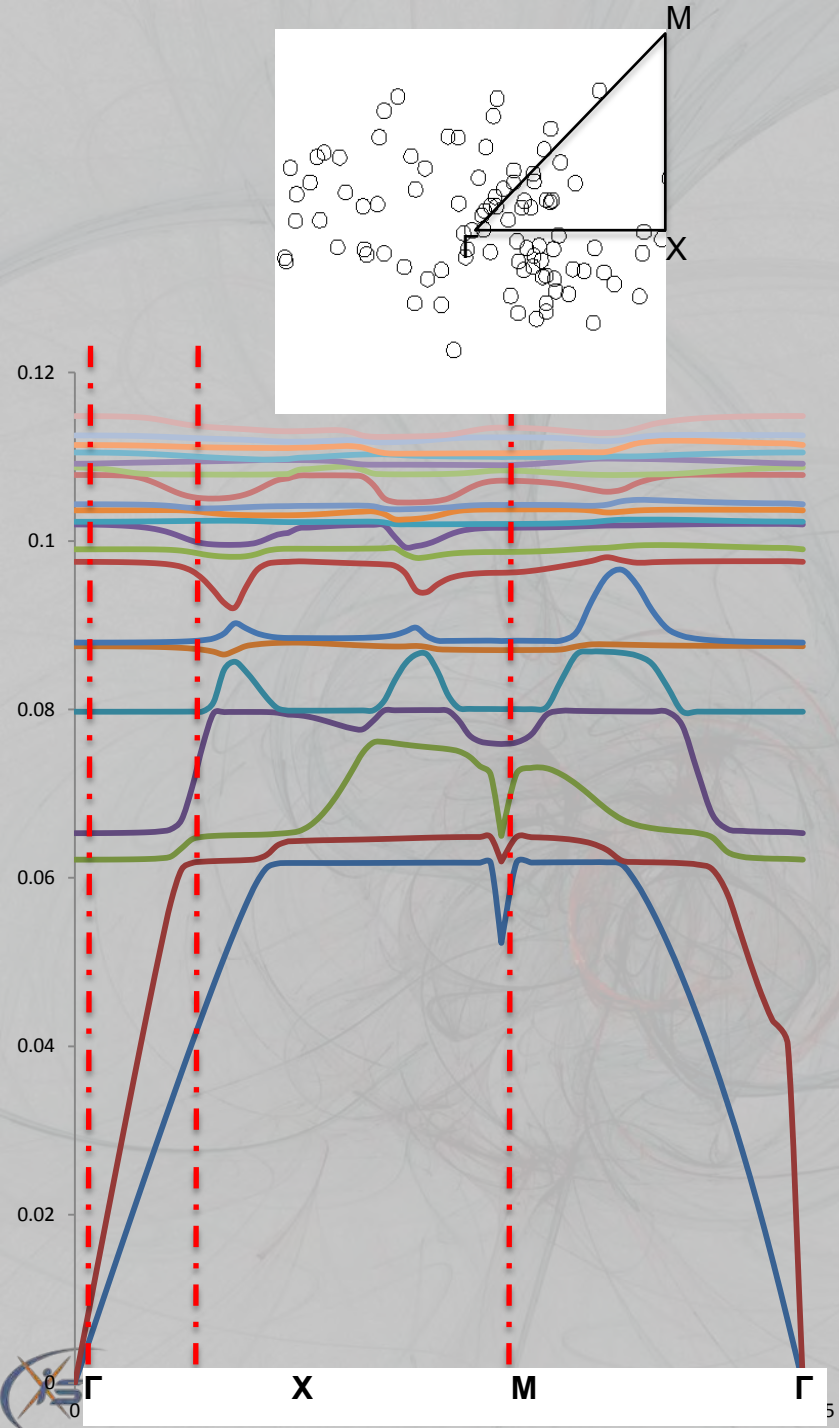
Non-Deterministic Fractal

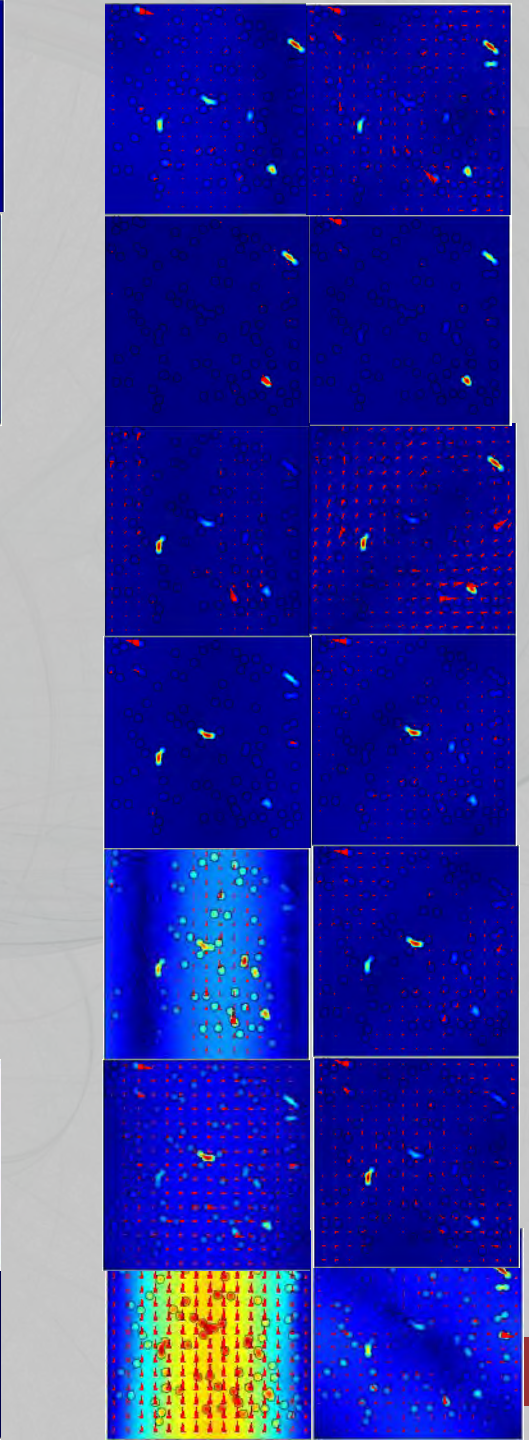
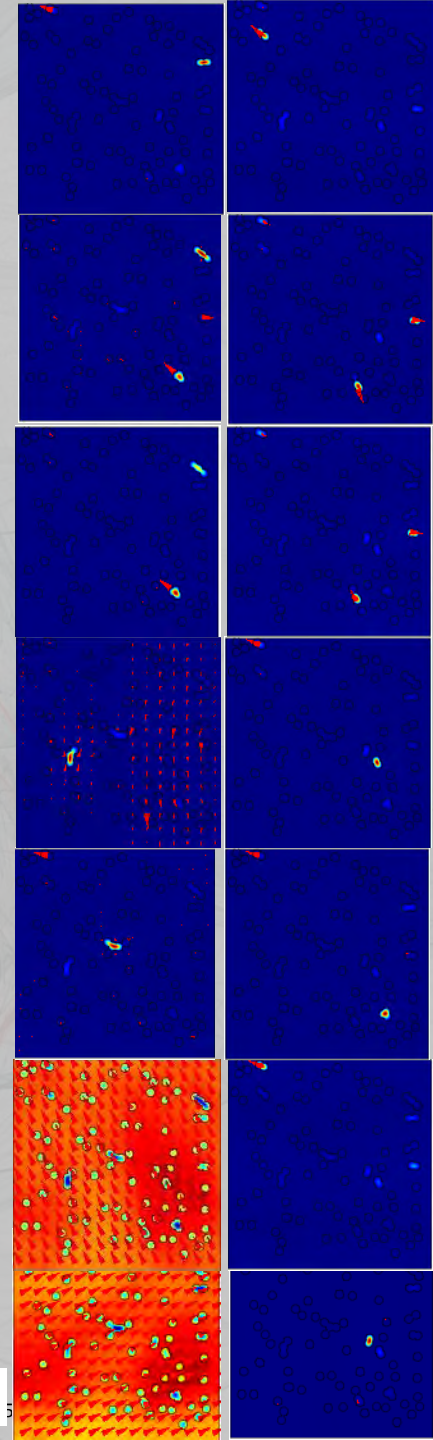
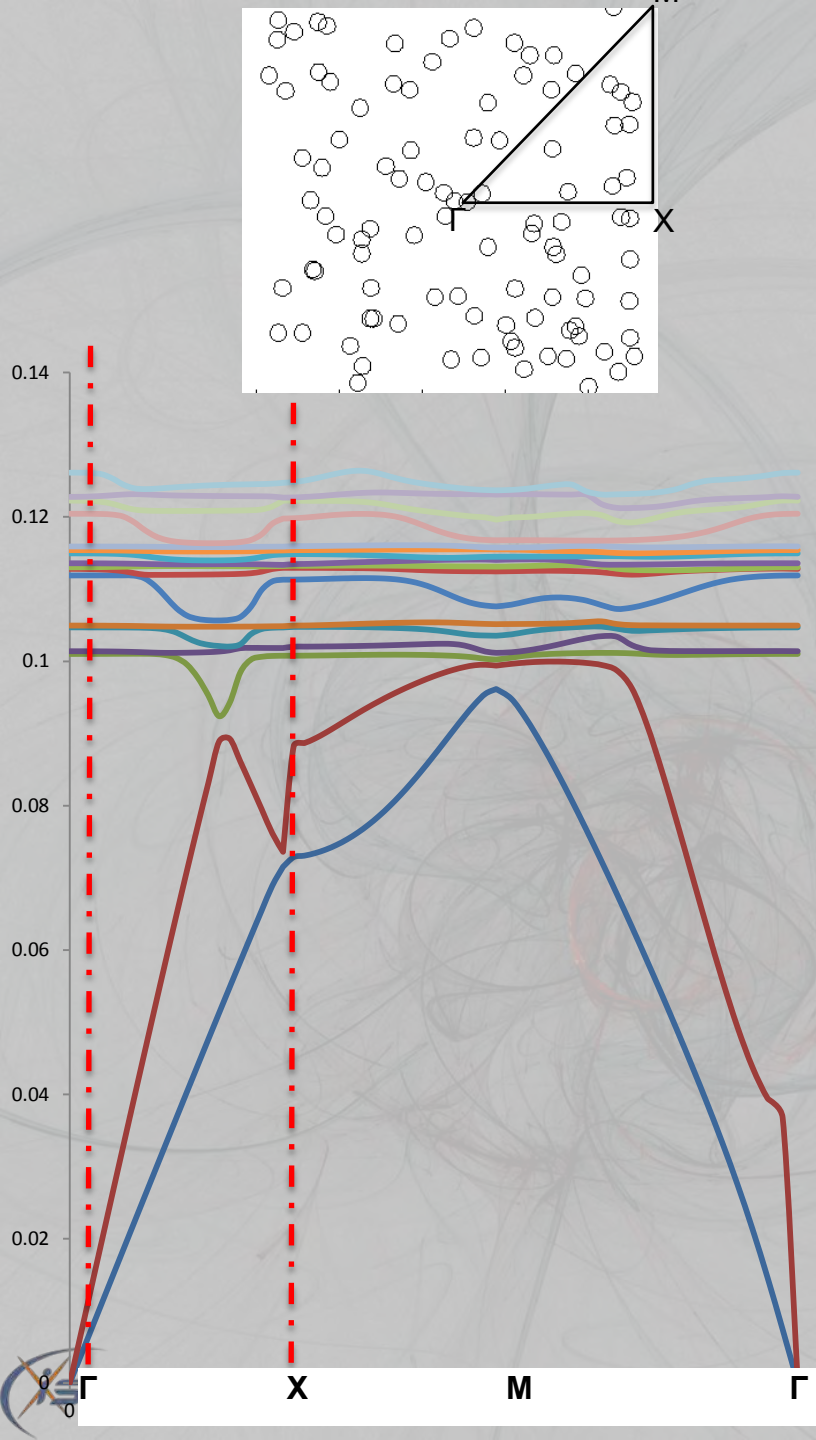
- Brownian fractal motion
 - B(t): $B(t) = b^{-H} B(bt)$
 - where H is referred to as the Hurst exponent
 - $H < 0.5$ implies antipersistent fluctuations,
 - $H > 0.5$ implies persistent
 - T is time and b is scalar ratio





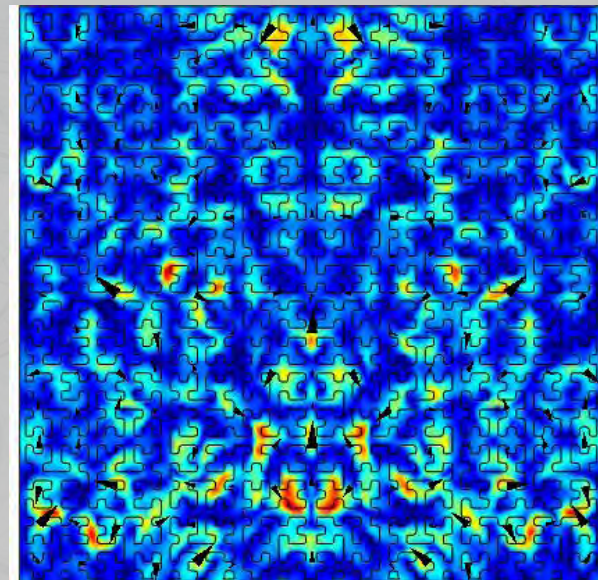






Potential Applications

- Nonlinear acoustic phenomena
- Broadband compact shielding devices
- Thermal conductivity engineering
- Smart Skin



Conclusion

- Phononic metamaterials based on fractal geometry has been investigated
 - The general framework proposed by Koh would be a powerful tool for designing and optimizing phononic devices
 - Preliminary study on H pattern and Hilbert Curve shows consistency with the framework.
- Potential applications of the metamaterials based on fractal geometry

Acknowledgement

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