# Theory for coupled photonic systems derived from first principles and its applications in line-shape tailoring

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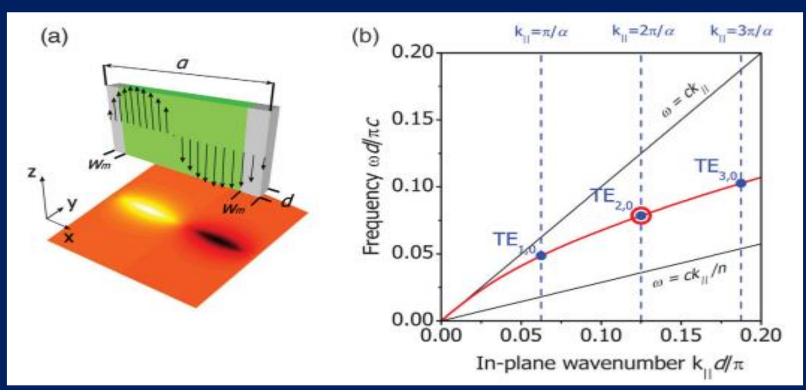
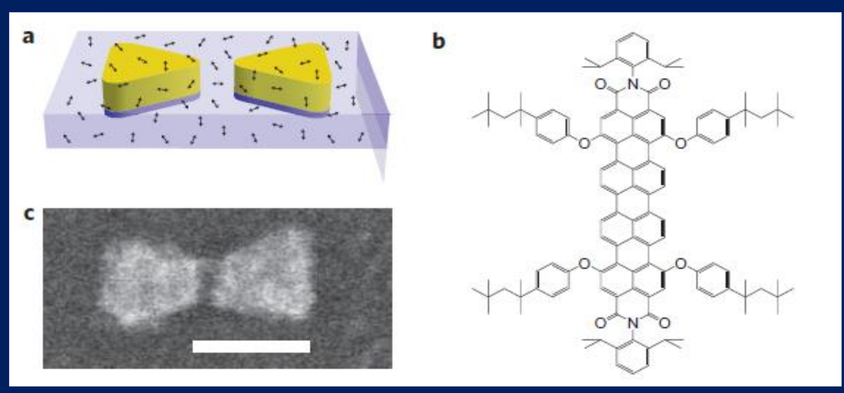
## I.Background and Motivations

**Coupled plasmonic systems play important roles**



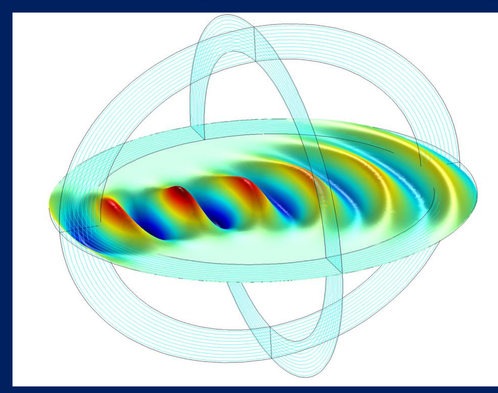
Soukoulis, et al. PRL(2017)



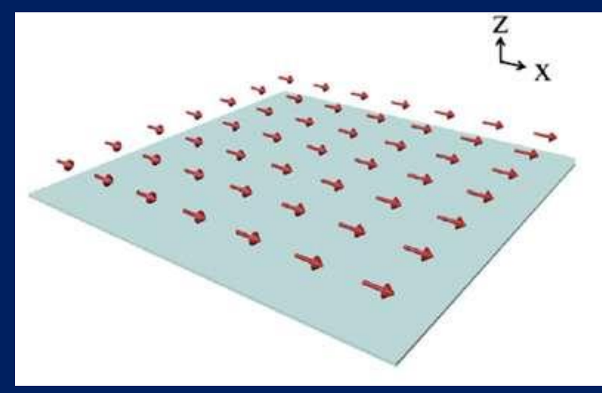
Fan, Moerner et al.Nature Photon. 2009

**Existing theories for plasmonic coupled system**

Numerical: simulation DDA etc.



Fitting: CMT dipolar model etx



LITTLE physical understandings

fitting & Cannot predict

**Lack a theory framework !**

## II. Development of the theory

### (1) A formal theory applicable to all kinds of waves

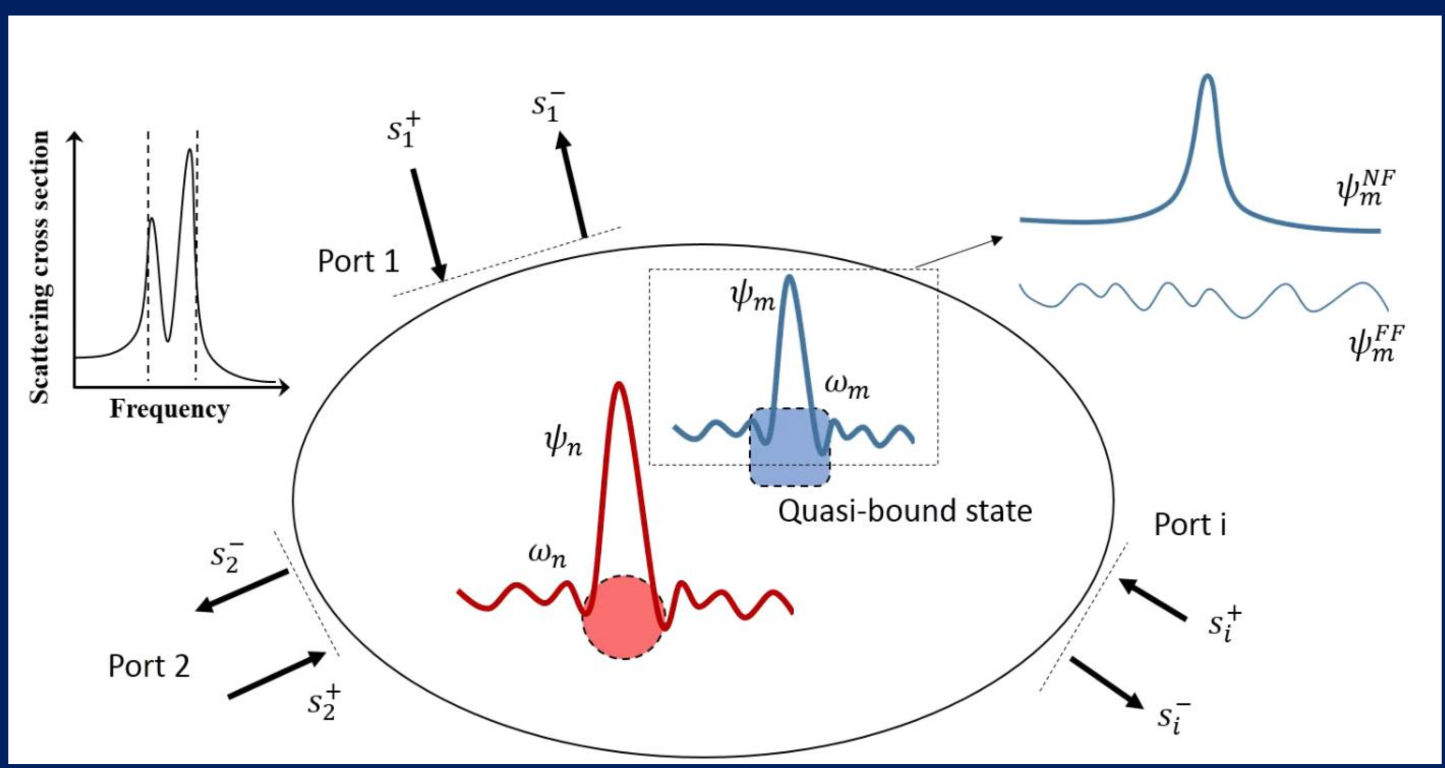


FIG. 1 Schematics of the coupled photonic systems and the quasibound state of an open system.

$$i\frac{\partial}{\partial t}|\Psi\rangle=\hat{\mathbf{H}}|\Psi\rangle \text{ with eigen functions } \begin{cases}|m\rangle=|m^{NF}\rangle+|m^{FF}\rangle(discrete)\\ |n\rangle(continue)\end{cases}$$

**Project :**

$$\dot{a}_m=-i\omega_m a_m-\Gamma_m a_m+\sum_{m'\neq m}(-it_{mm'})a_{m'}+\sum_{m'\neq m}X_{mm'}a_{m'}+\sum_n\kappa_{mn}s_n^+$$

$$s_n^-=\sum_{n'}c_{nn'}s_{n'}+\sum_m d_{nm}a_m$$

**with:**

$$\Gamma_m=\langle m^{NF}|V_m|m^{FF}\rangle_V \quad X_{mm'}=\langle m^{NF}|V_m|m'^{FF}\rangle_V \quad \kappa_{mn}=\langle m^{NF}|V_m|n^+\rangle_V$$

$$d_{nm}=\langle n^-|m^{FF}\rangle_S$$

**all parameters obtaind directly**

### (2) Experimental verifications

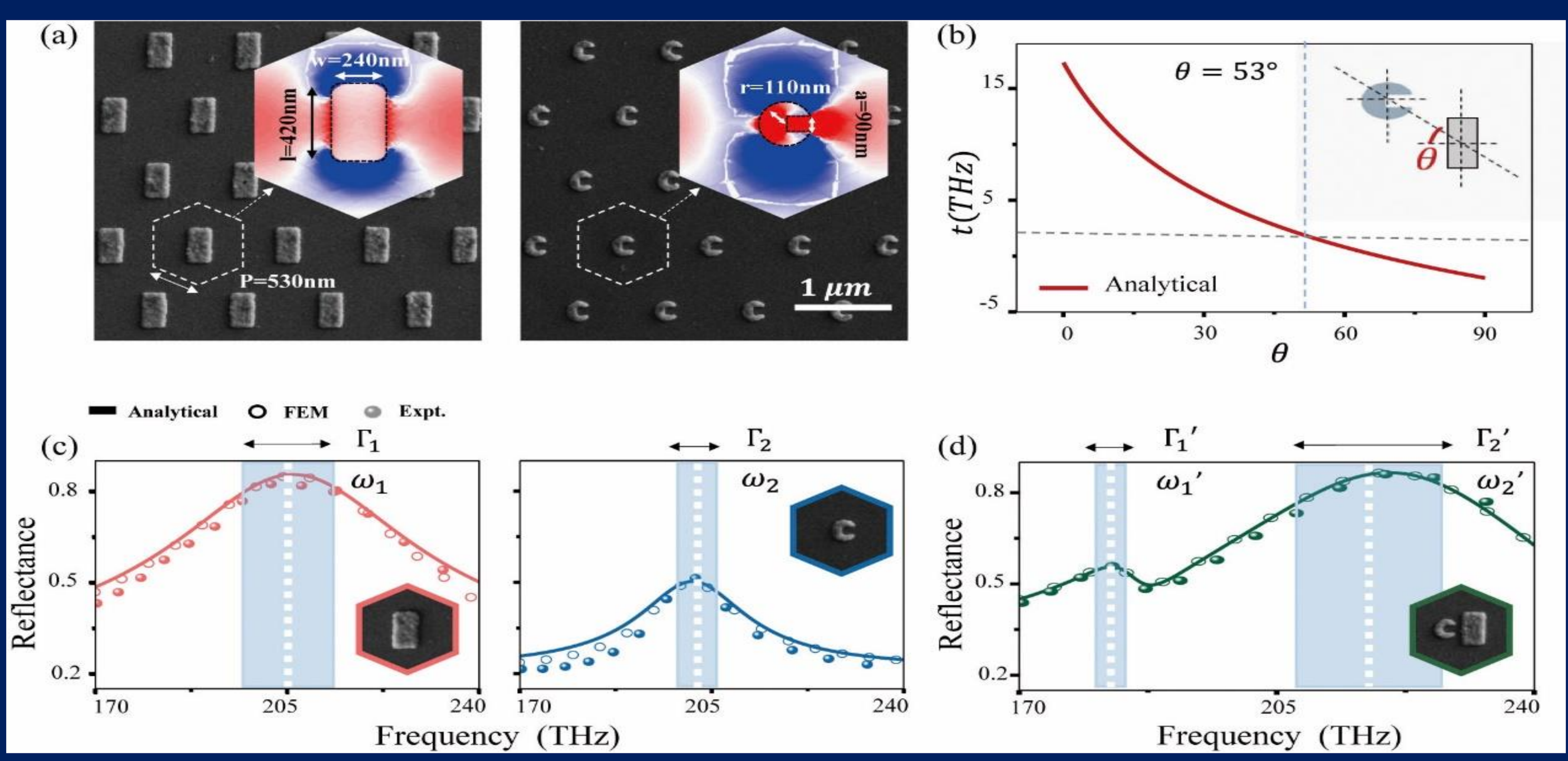


FIG. 3 Therotical(line),simulated(circle) and experimental (solid ciecle) reflectance of the system .

## III. Phase diagram for guiding line-shape design

$$\mathbf{H}=\begin{pmatrix}\omega_1-i\Gamma_1 & t_{12}+iX_{12}\\ t_{21}+iX_{21} & \omega_2-i\Gamma_2\end{pmatrix}\rightarrow\begin{pmatrix}\tilde{\omega}_1-i\tilde{\Gamma}_1 & 0\\ 0 & \tilde{\omega}_2-i\tilde{\Gamma}_2\end{pmatrix}$$

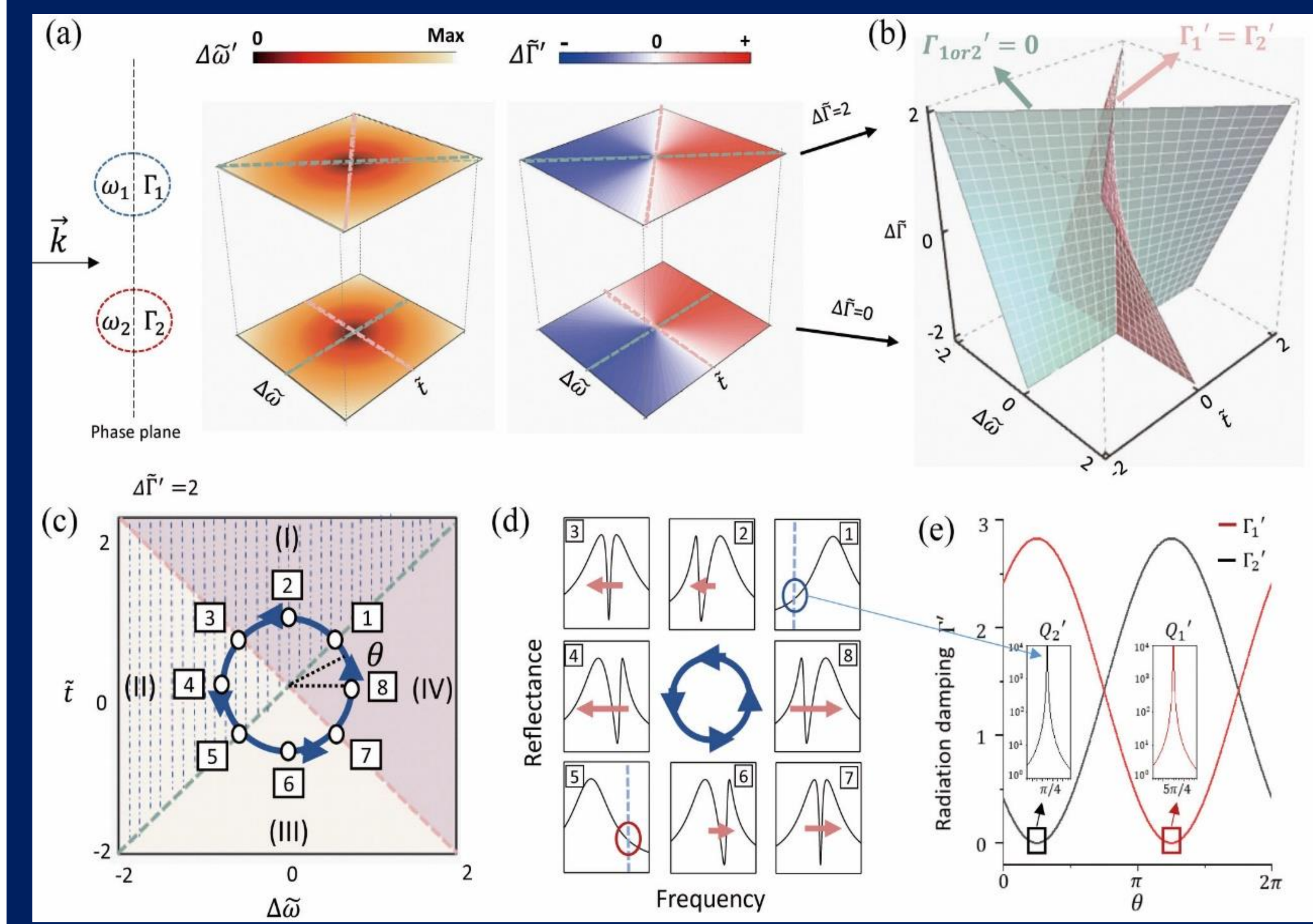


FIG. 4. Schematics of (a) the system contains of two modes in a phase plane.

## IV. Experimental verification: line-shape control by design wavefunction

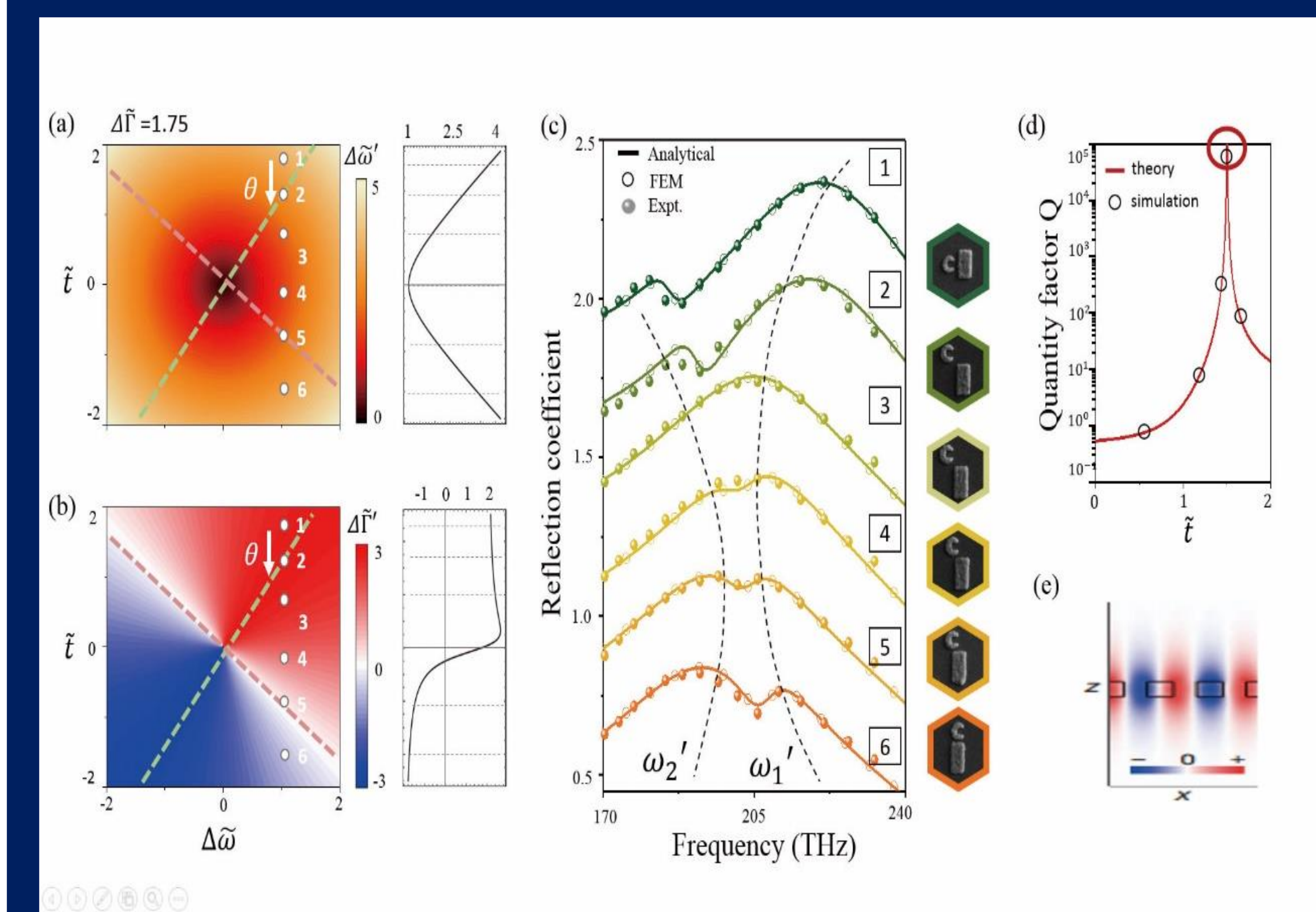


FIG. 4 Therotical(line),simulated(circle) and experimental (solid ciecle) reflectance of the system .

## Conclusions

- Established a theory for coupled photonic systems derived from first principles.
- We can predict interesting optical effects in complex plasmonic system

## References

[1] Xi, B., Xu, H., Xu, Xiao.S., & Zhou, L. Phys. Rev. B. 83, 165115(2011).
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