Physics
OSAKA UNIVERSITY

原子ニュートリノ過程における QEDバックグラウンドの抑制

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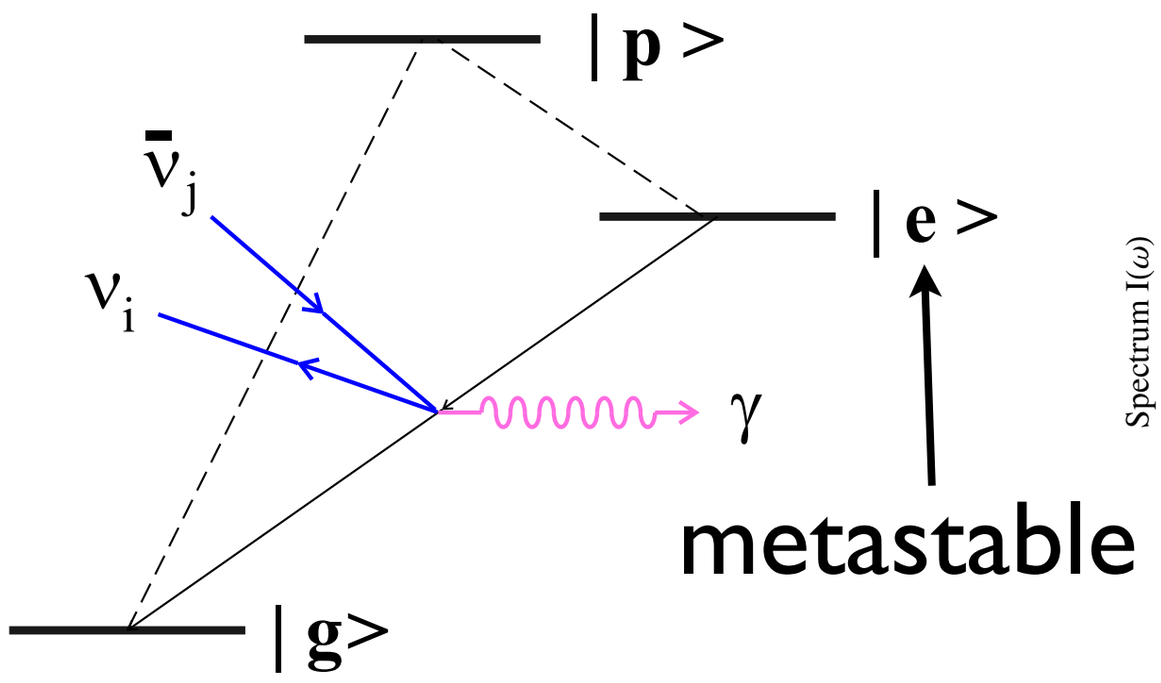
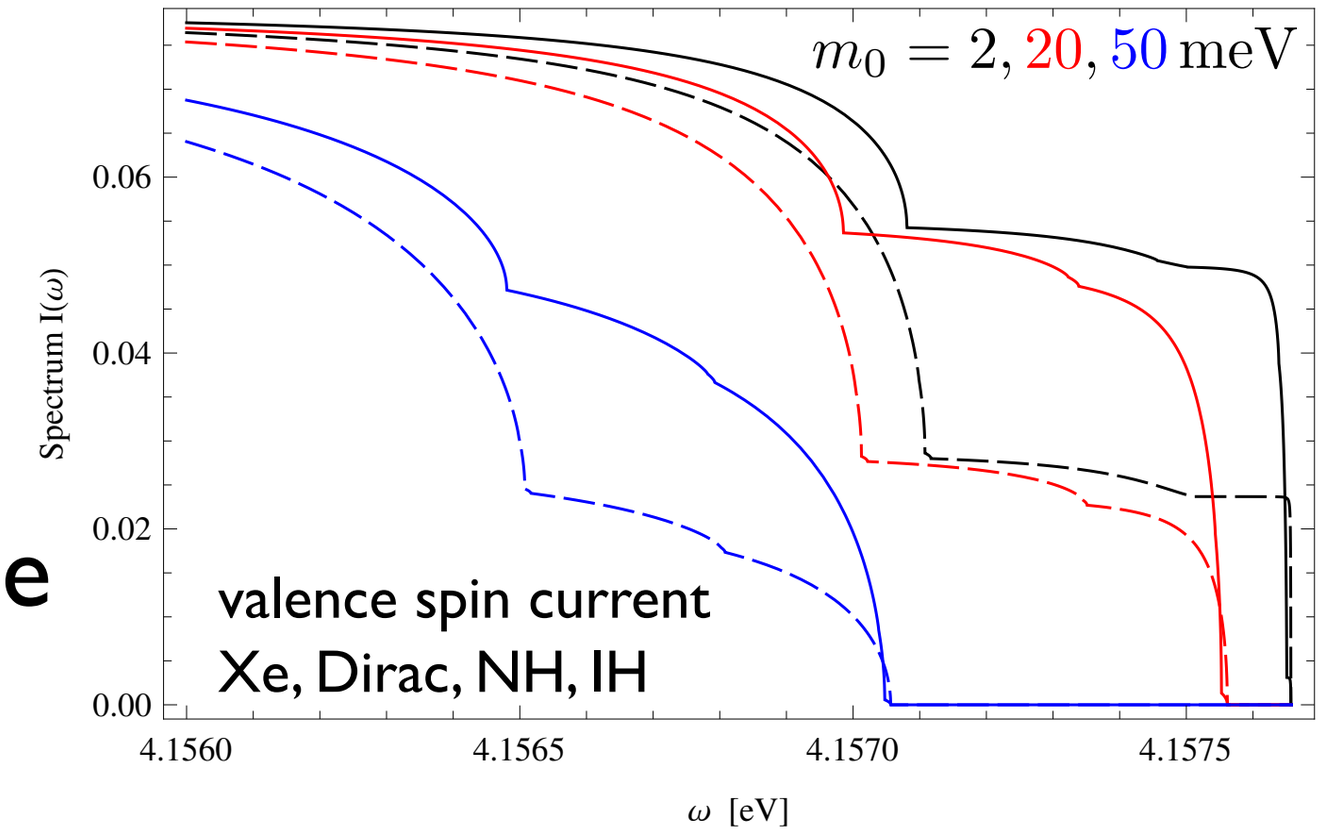
日本物理学会第71年次大会 @ 東北学院大学泉キャンパス, 2016/3/19

Radiative Emission of Neutrino Pair (RENP)

A.Fukumi et al. PTEP (2012) 04D002; arXiv:1211.4904

D.N. Dinh, S.T. Petcov, N. Sasao, M.T., M.Yoshimura, PLB719(2013)154; arXiv:1209.4808

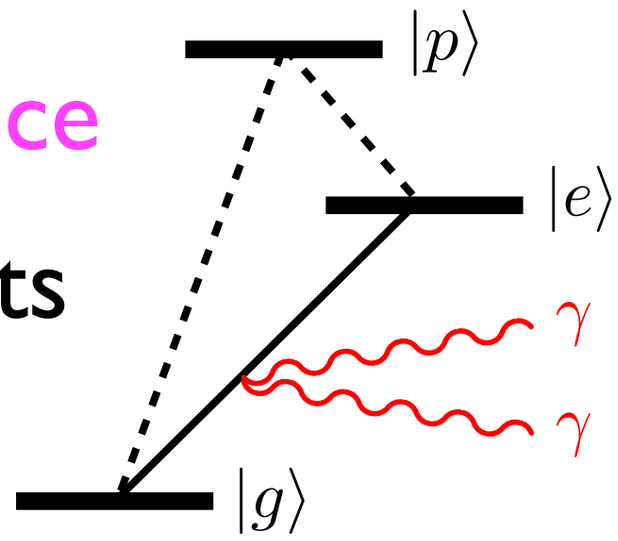




Rate enhancement by macrocoherence

→ Confirmed by PSR experiments

10^{18} amplification



QED backgrounds

M. Yoshimura, N. Sasao, MT
PTEP (2015) 053B06; arXiv:15010571

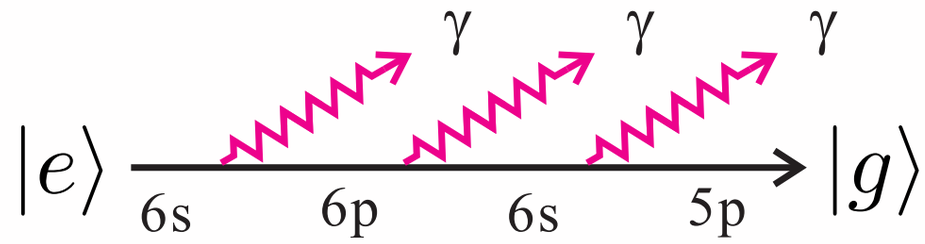
Macrocoherent amplification of RENP

$$|e\rangle \to |g\rangle + \gamma + \nu_i \bar{\nu}_j$$

Macrocoherent amplification of QED processes

$$|e\rangle \to |g\rangle + \gamma_0 + \gamma_1 \gamma_2 \quad \textbf{McQ3}$$

Ex. Xe



$$\Gamma(\mathrm{McQ3}) \sim 10^{20}\ \mathrm{Hz} \left(\frac{n}{10^{20}/\mathrm{cm}^3} \right)^3 \frac{V}{\mathrm{cm}^3} \frac{\eta_3(t)}{10^{-3}}$$

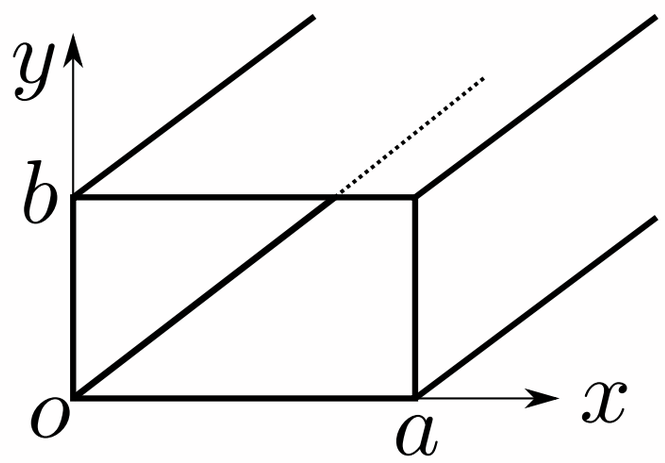
cf. $\Gamma(\mathrm{RENP}) \sim 1\ \mathrm{mHz} \left(\frac{n}{10^{20}/\mathrm{cm}^3} \right)^3 \frac{V}{\mathrm{cm}^3} \frac{\eta_\omega(t)}{10^{-3}}$

serious BG though reducible

McQn vs. RENP in a waveguide

TE modes

$$H_z \sim \cos\left(\frac{n_x \pi}{a} x\right) \cos\left(\frac{n_y \pi}{b} y\right) e^{i(kz - \omega t)}$$



Dispersion: $\omega^2 = k^2 + \omega_c^2$

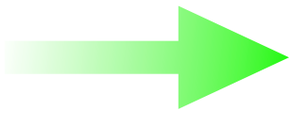
Cutoff freq. (Mass): $\omega_c^2 = M^2 = \pi^2 \left(\frac{n_x^2}{a^2} + \frac{n_y^2}{b^2} \right)$

The lowest mode: $\mathrm{TE}_{1,0}$ $M = \pi/a$

Threshold

McQn $\omega \leq \epsilon_{eg}/2 - n(n-2)M^2/2\epsilon_{eg}$

RENP $\omega \leq \epsilon_{eg}/2 - [(m_i+m_j)^2 - M^2]/2\epsilon_{eg}$



$(n-1)M > m_i + m_j$ BG-free RENP

McQ3

$M > (m_i+m_j)/2 \geq m_0$ (the smallest neutrino mass)

$$M = \frac{\pi}{a} \simeq 0.6 \text{ meV} \left(\frac{1\text{mm}}{a}\right)$$

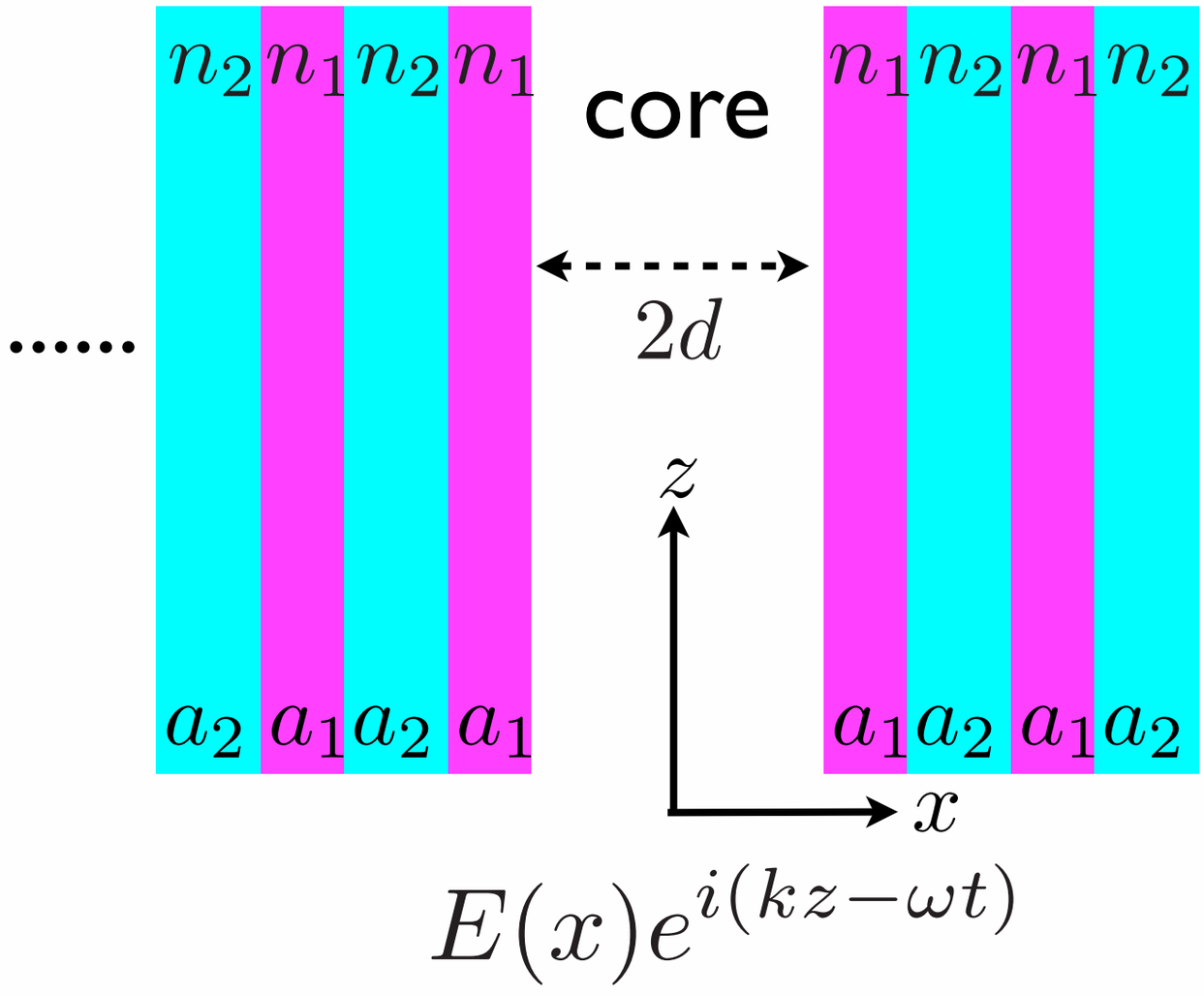
Ex. Xe $\epsilon_{eg} = 8.3153$ eV $\quad m_0 = 1$ meV, $a = 10$ μm

$$\omega_{\max}(\text{McQ3}) = 4.1570 \text{ eV}$$
$$\omega_{\max}(\text{RENP}) = 4.1579 \text{ eV}$$

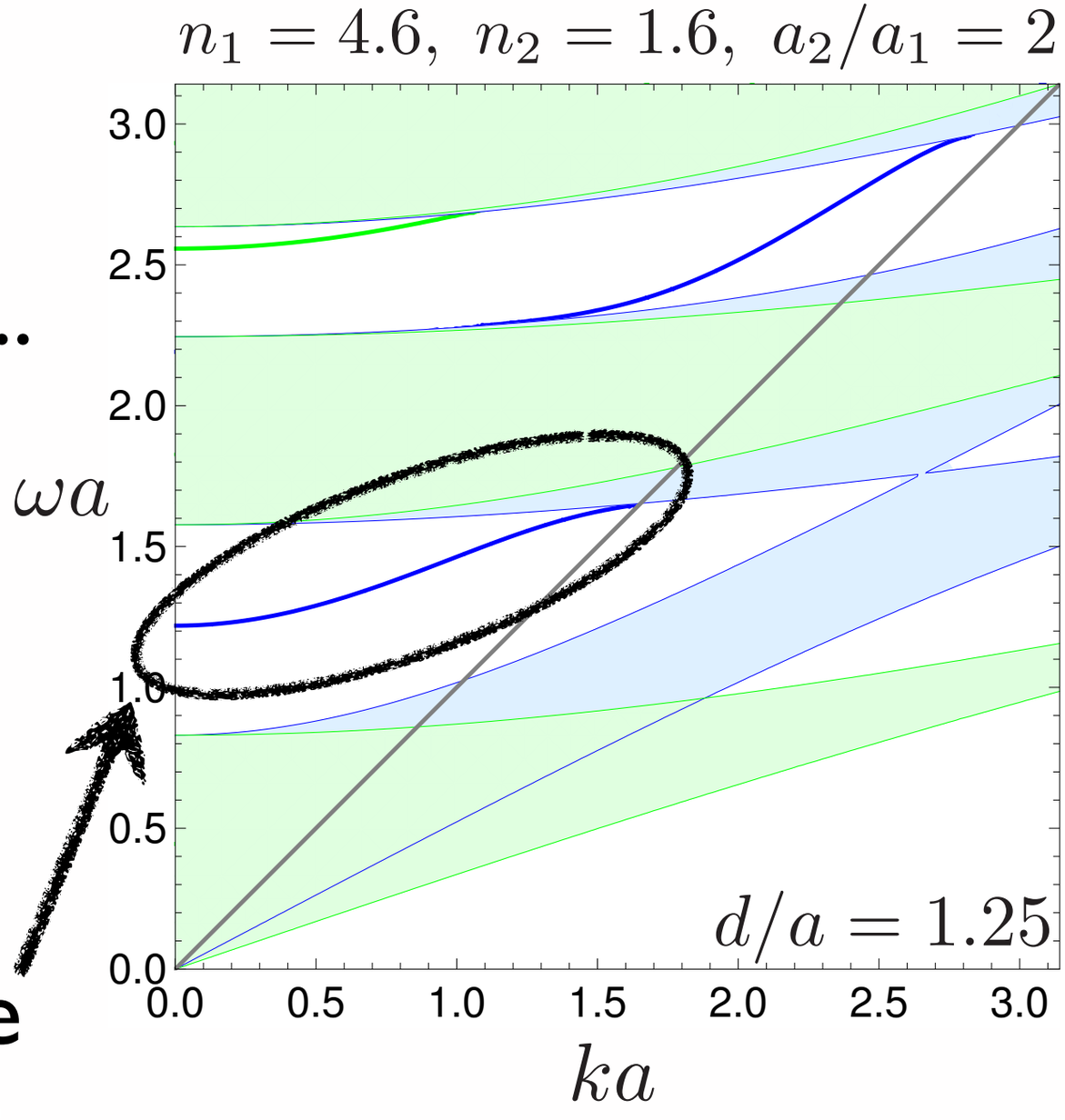
Photonic crystals may be realistic.

Slab waveguide

Yeh, Yariv, Hong, J. Opt. Soc. Am. 67, 423 (1977)



$$E(x)e^{i(kz-\omega t)}$$



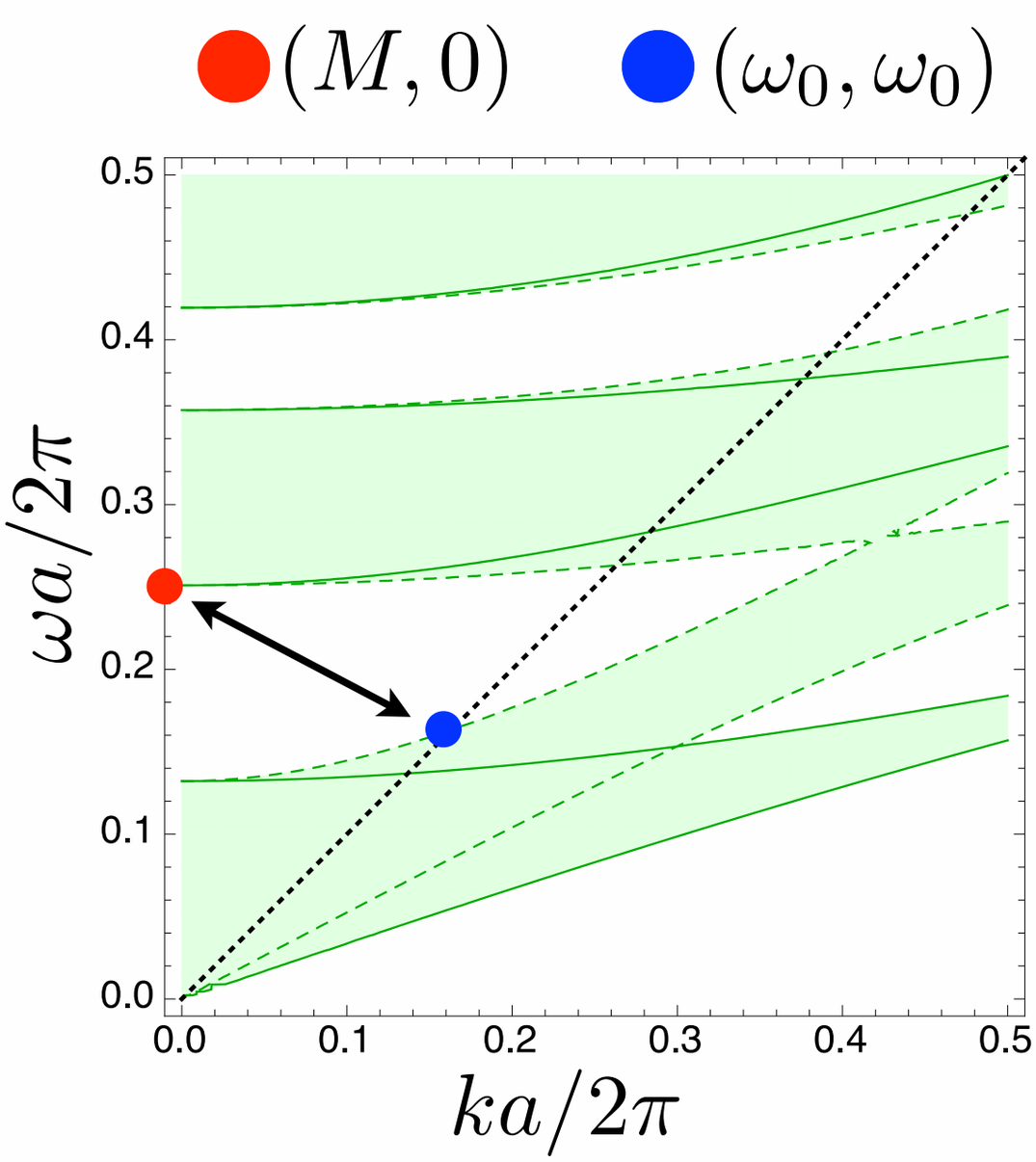
Localized modes in the core
similar dispersion relations
as metal waveguides

TM TE

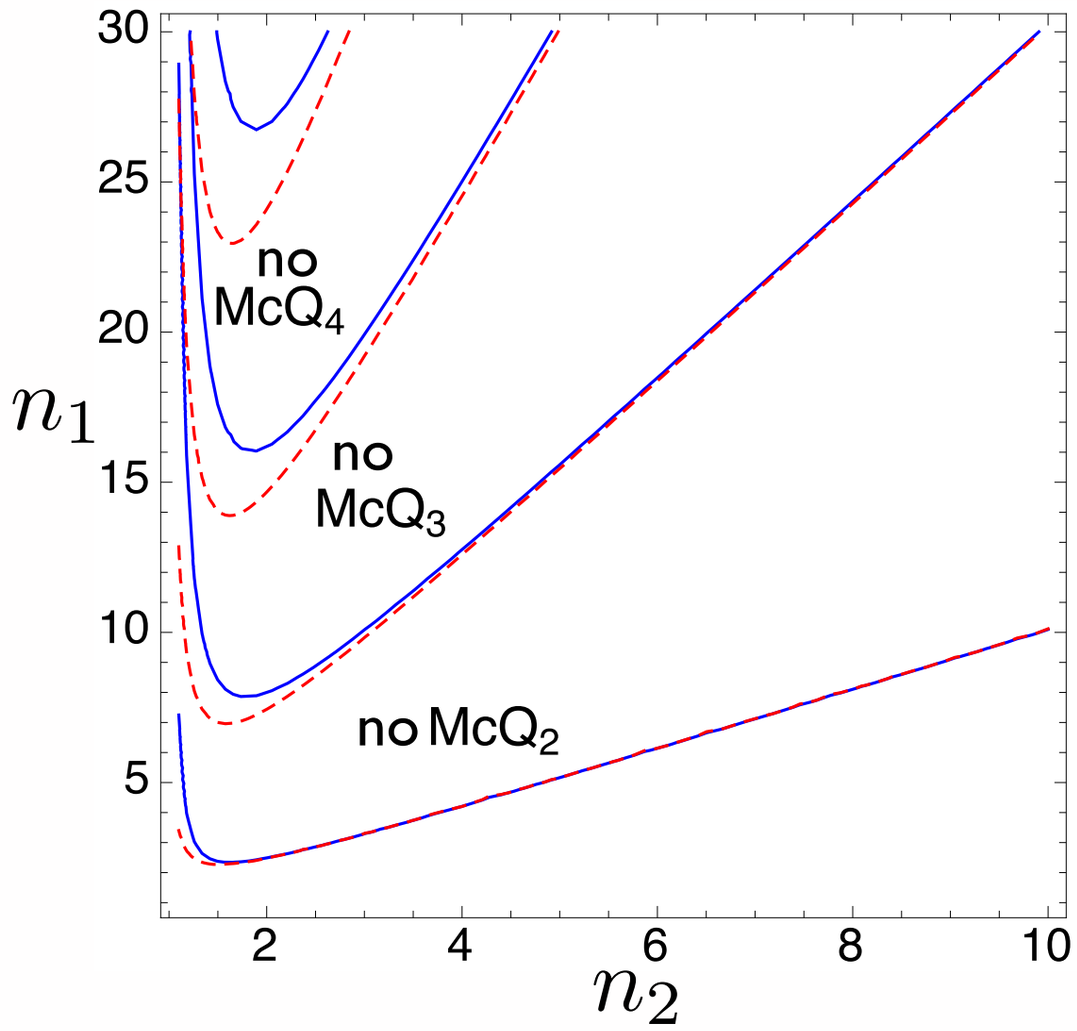
Required indices to exclude McQn

Allowed bands exist. (different from metal w.g.)

→ wide band gap for prohibiting McQn



$\omega_0/M < 1/(n-1)$
for no McQn



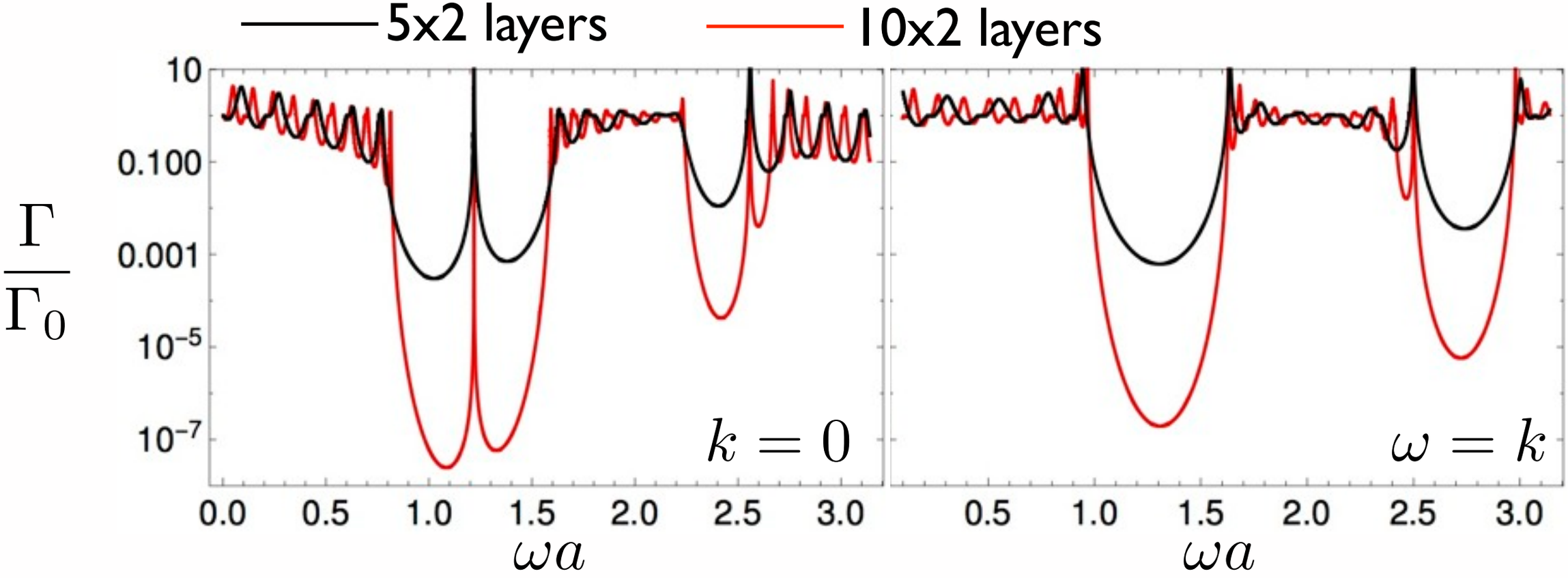
Rate suppression in the band gap

Infinite periodic slab

no state in the band gap, complete prohibition

Finite periodic slab

finite state in the band gap, incomplete prohibition



Suppression of QED BG for RENP

- Cutoff of the mode in a waveguide

  ~ photon mass > neutrino mass

  → Background-free RENP

- Realization with photonic crystals

  large index contrast required

  exponential suppression of BG rate
  in the band gap expected

- To do

  rate of McQ4 or higher (work in progress)