PT breaking in rings and competing potentials

Yogesh N. Joglekar
Indiana University - Purdue University Indianapolis (IUPUI)

PARIS 2012

Main collaborators: Derek Scott, Bijan Bagchi
Phys. Rev. A **84**, 062105 (2012)
arXiv:1207.1945, arXiv:1206.3310

Outline

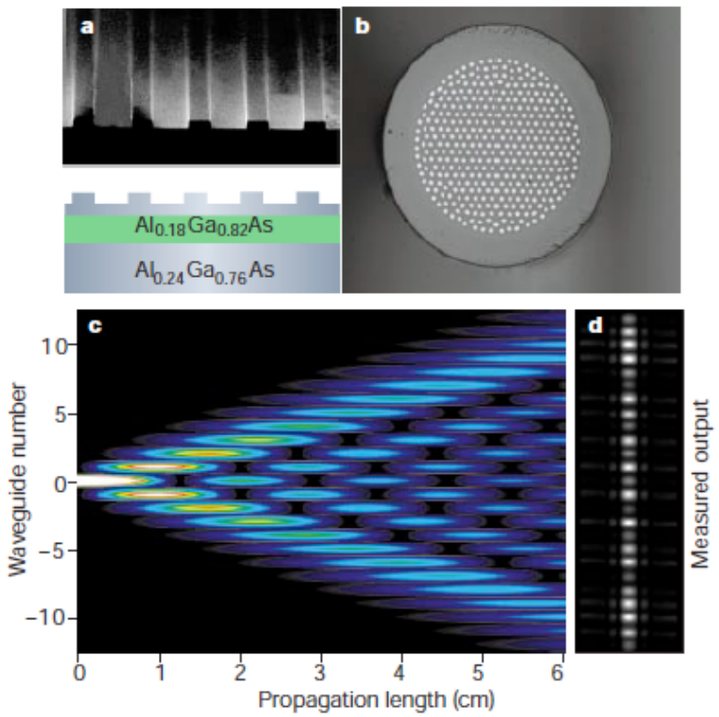
Introduction: experimental realizations

Lattice ring model: Results: PT phase diagram, Chirality across PT breaking

Particle in a box with two PT potentials: Results: PT phase diagram, Re-entrant PT Phase.

Conclusions: STEM student involvement

Experimental lattice models: sites=impurities



Christodoulides et al. Nature 2003

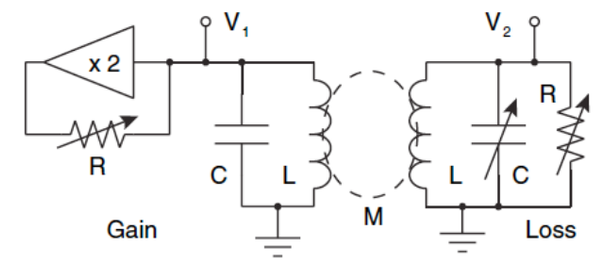
RAPID COMMUNICATIONS

PHYSICAL REVIEW A 84, 040101(R) (2011)

SCHINDLER, LI, ZHENG, ELLIS, AND KOTTOS

Experimental study of active *LRC* circuits with $\mathcal{PT}$ symmetries

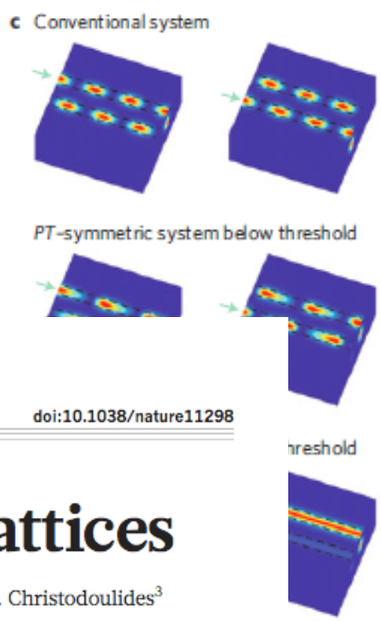
Joseph Schindler, Ang Li, Mei C. Zheng, F. M. Ellis, and Tsampikos Kottos
Department of Physics, Wesleyan University, Middletown, Connecticut 06459, USA
(Received 28 June 2011; revised manuscript received 31 August 2011; published 13 October 2011)



LETTERS
PUBLISHED ONLINE: 24 JANUARY 2010 | DOI:10.1038/NPHYS1515
nature physics

Observation of parity-time symmetry in optics

Christian E. Rüter[1], Konstantinos G. Makris[2], Ramy El-Ganainy[2], Demetrios N. Christodoulides[2], Mordechai Segev[3] and Detlef Kip[1]*



Nonreciprocal Light Propagation in a Silicon Photonic Circuit

Liang Feng,[1,2,4]*† Maurice Ayache,[3]* Jingqing Huang,[1,4]* Ye-Long Xu,[2] Ming-Hui Lu,[2] Yan-Feng Chen,[2]† Yeshaiahu Fainman,[3] Axel Scherer[1,4]†

Optical communications and computing require on-chip nonreciprocal light propagation to isolate and stabilize different chip-scale optical components. We have designed and fabricated a metallic-silicon waveguide system in which the optical potential is modulated along the length of the waveguide such that nonreciprocal light propagation is obtained on a silicon photonic chip. Nonreciprocal light transport and one-way photonic mode conversion are demonstrated at the wavelength of 1.55 micrometers in both simulations and experiments. Our system is compatible with conventional complementary metal-oxide-semiconductor processing, providing a way to chip-scale optical isolators for optical communications and computing.

ing (*13*) a
generatio
on-chip n
optical isc
Parity-
mechanic
mechanics
Hamiltoni
tirely real
metry (*15*, *16*). Due to
the Schrödinger equatio
and the wave equation ir
been studied in the re
Hermitian optical potenti
of PT symmetry has rec
observed, showing asym
verse to light propagatio
(*20*, *21*). Here, we have

ARTICLE
doi:10.1038/nature11298

Parity–time synthetic photonic lattices

Alois Regensburger[1,2], Christoph Bersch[1,2], Mohammad-Ali Miri[3], Georgy Onishchukov[2], Demetrios N. Christodoulides[3] & Ulf Peschel[1]

Observation of $\mathcal{PT}$ phase transition in a simple mechanical system

Carl M. Bender[1]*, Bjorn K. Berntson[2]†, David Parker[1]‡, and E. Samuel[1]§

[1] *Department of Physics, King's College London, Strand, London WC2R 1LS, UK*
[2] *Blackett Laboratory, Imperial College, London SW7 2AZ, UK*
(Dated: June 22, 2012)

PT-symmetric two-tunneling ring

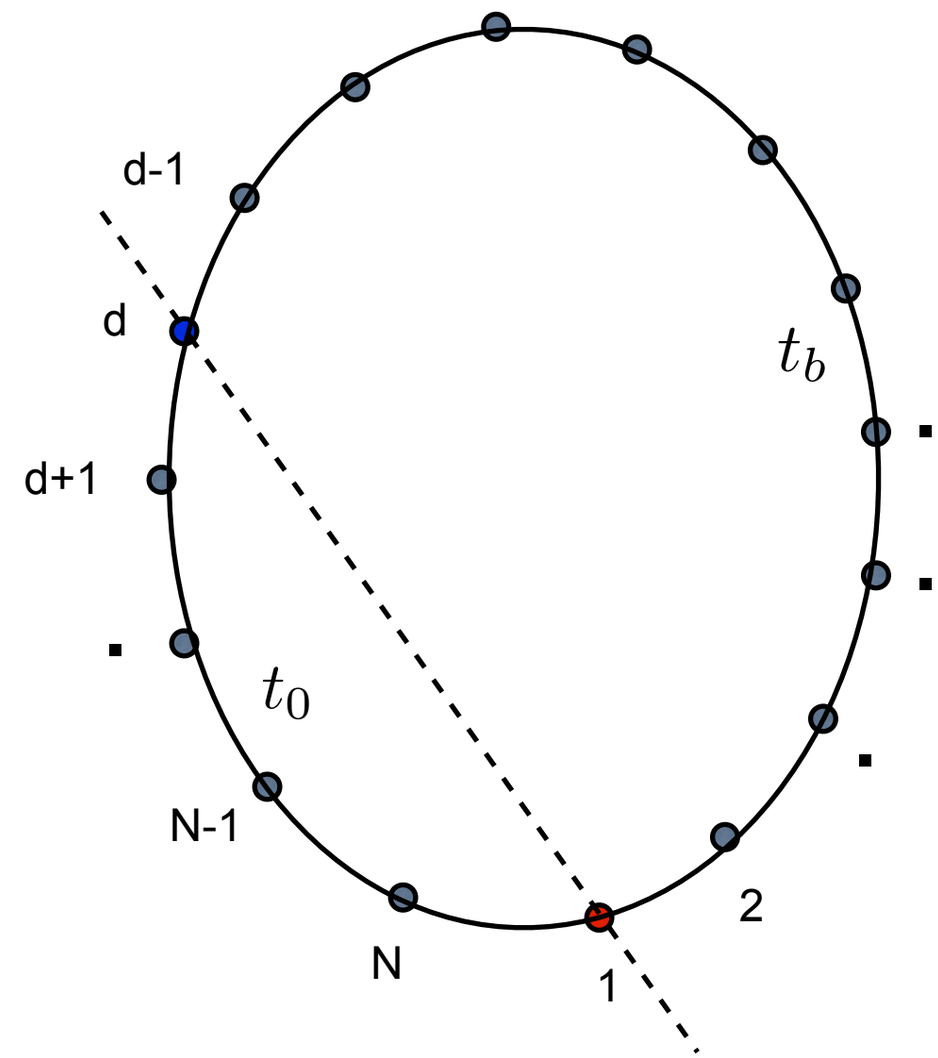
Tight-binding hopping

$$H_0 = -\sum_{i=1}^{N} t(i)\left[|i\rangle\langle i+1| + |i+1\rangle\langle i|\right]$$

Single loss-gain pair

$$V = i\gamma\left[|1\rangle\langle 1| - |d\rangle\langle d|\right] \neq V^\dagger$$

Any loss, gain positions ok!

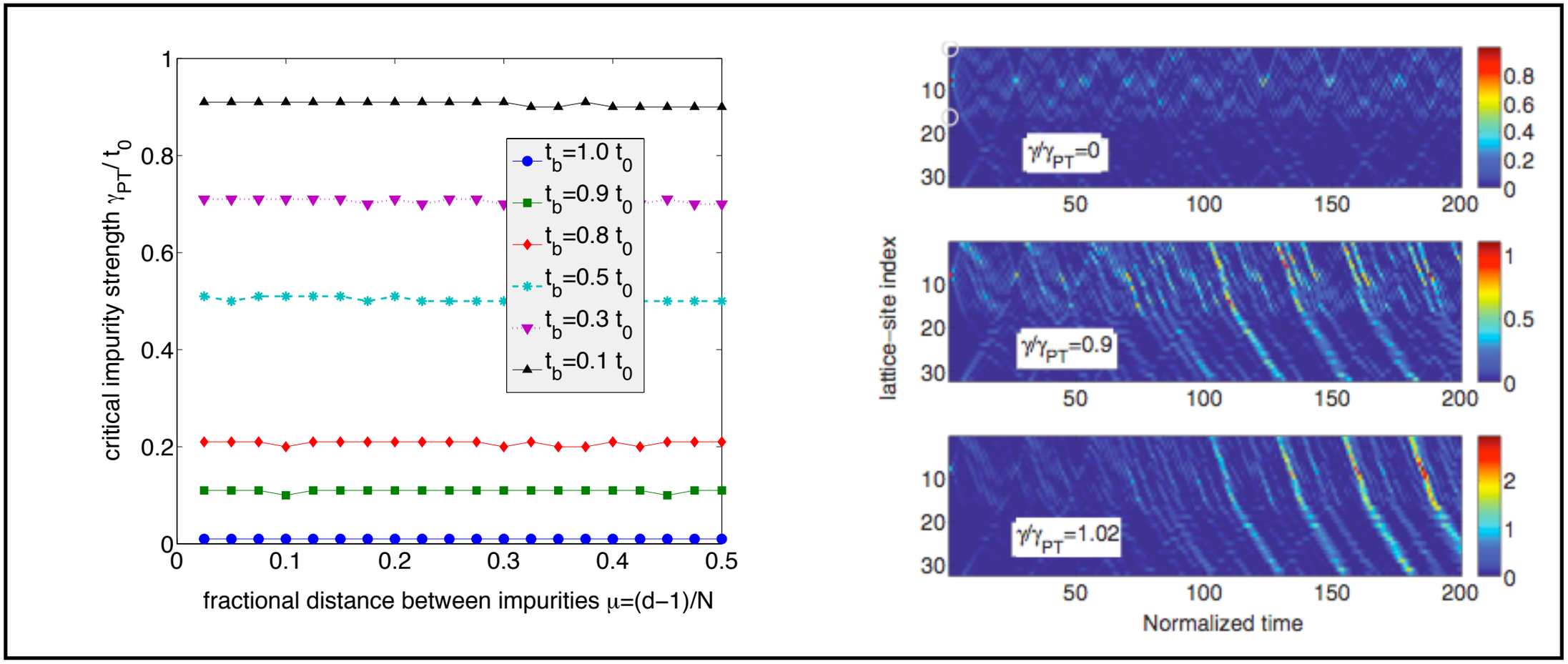


When does the PT ring have a real spectrum?
How does it depend upon the inter-impurity distance?

Phys. Rev. A **84**, 062105 (2012)

PT-breaking signatures in a ring

Predictions for phase diagram of a two-tunneling ring

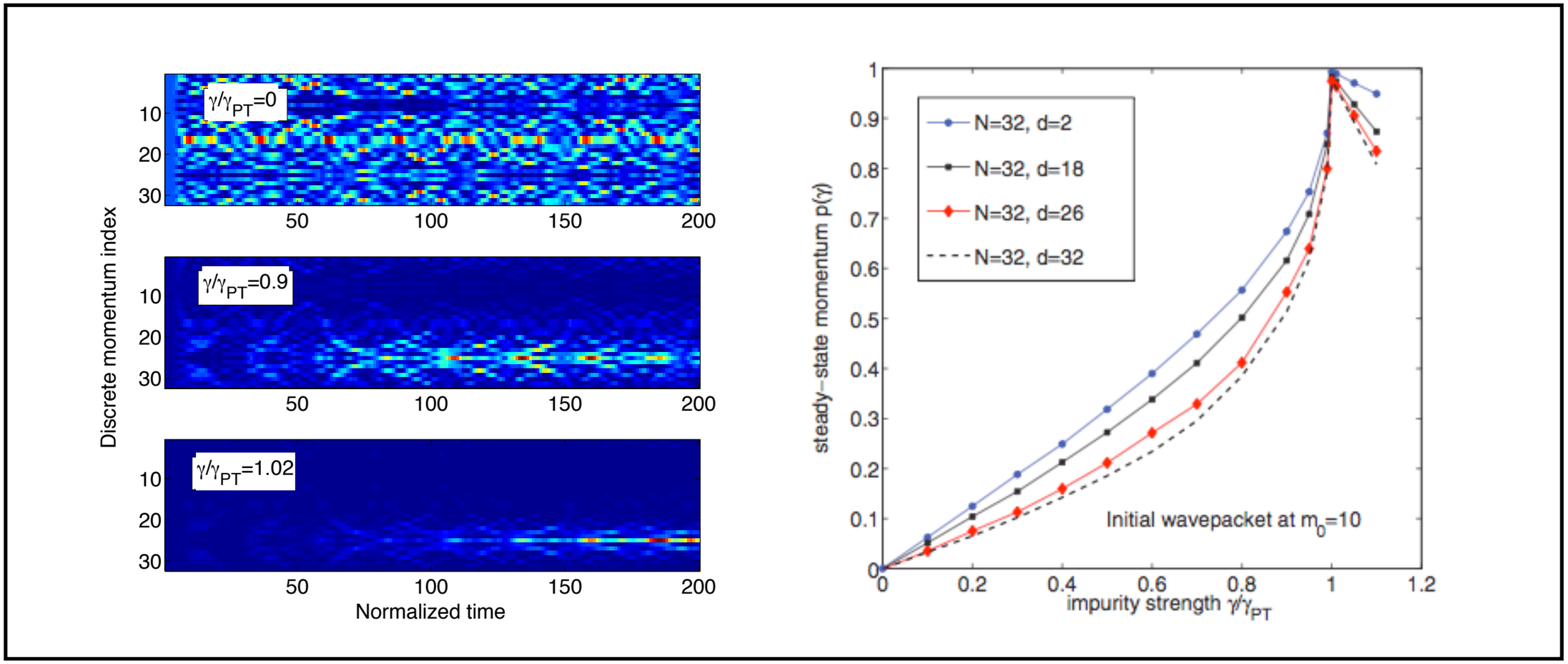


PT-breaking threshold independent of loss-gain distance.
Wave packet evolution becomes chiral for nonzero loss/gain.

Phys. Rev. A **84**, 062105 (2012)

PT-breaking signatures in a ring

Predictions for transverse momentum in a PT symmetric ring



After PT-breaking: Intensity increases exponentially with time
Chirality (momentum) shows a maximum at PT threshold

Particle in a box: competing PT potentials

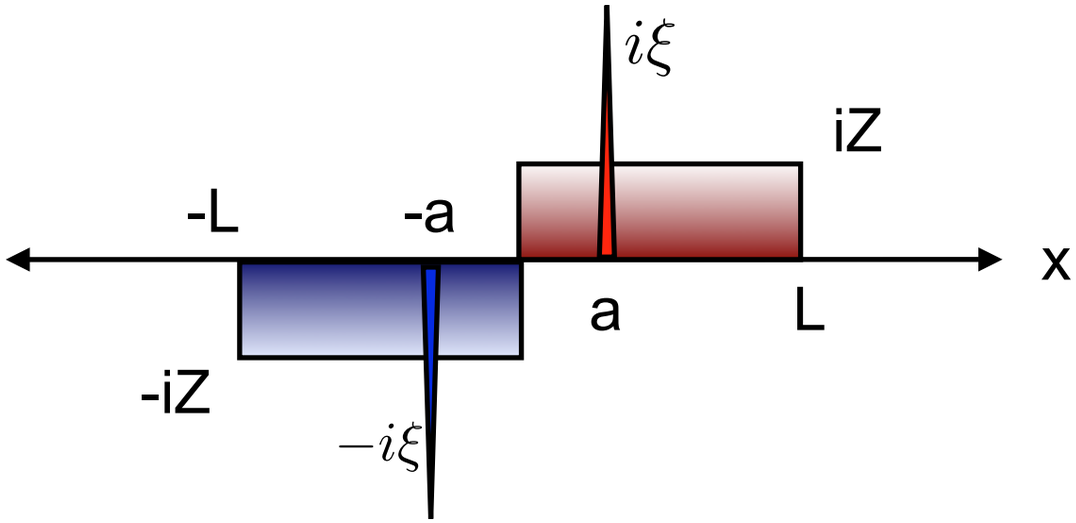
Short-range PT potential

$$V_\xi(x) = i\xi\left[\delta(x-a) - \delta(x+a)\right]$$

Broad, constant PT potential

$$V_Z(x) = iZ\mathrm{sign}(x)$$

Both have nonzero critical strengths in relevant units



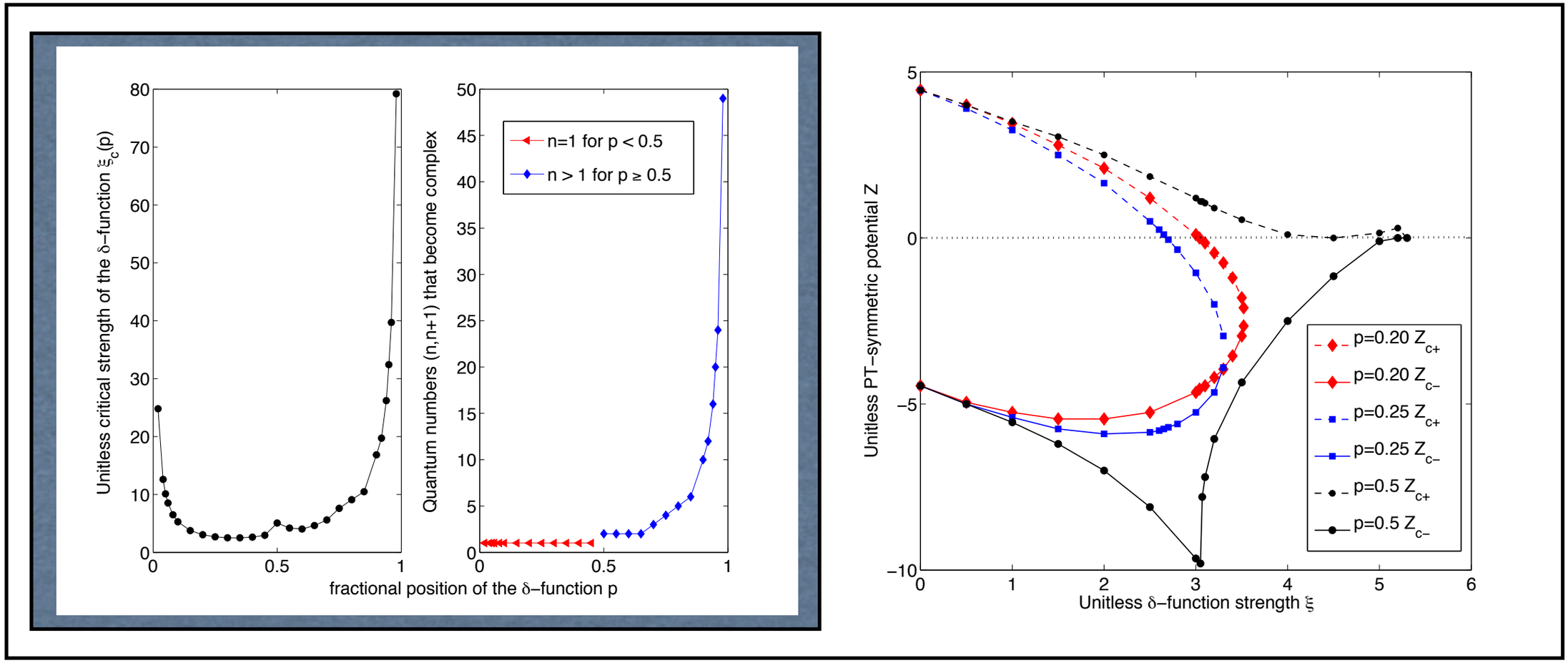
$$Z_c \sim 4.48$$
$$\xi_c(a = L/2) \sim 5.06$$

Znojil PLA 2001, JPA 2005; Mostazadeh JPA 2004

What is the effect of both on the PT phase?

arXiv:1206.3310

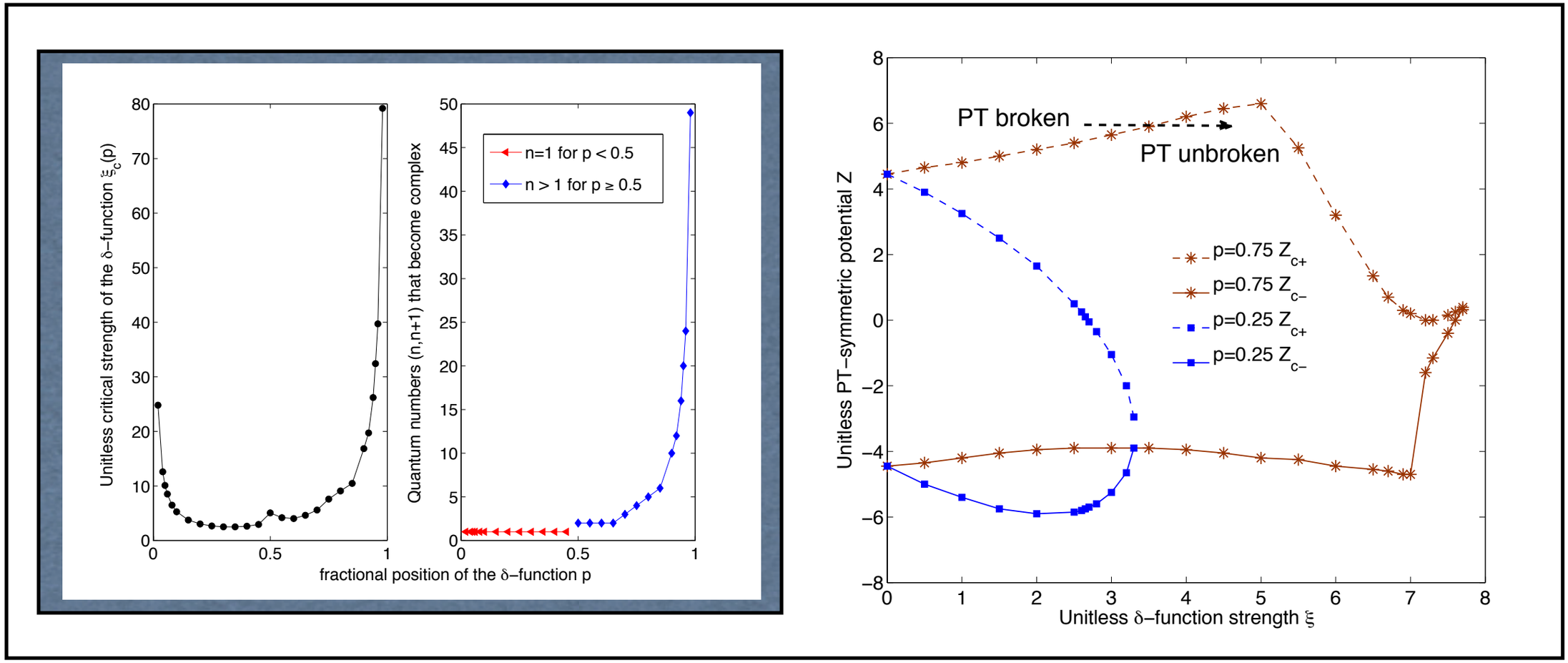
Particle in a box: competing PT potentials



The critical strength diverges as a/L approaches one.
For positions p=a/L < 0.5, the phase diagram is simple.

arXiv:1206.3310

Reentrant PT-symmetric phase!



We predict that a PT-phase is restored by adding localized loss to the broad-loss region!

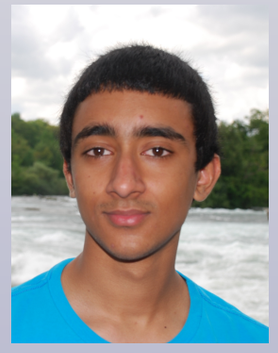
Conclusions

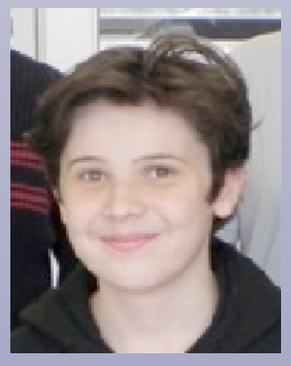
- Systems with balanced loss and gain.
- PT breaking accompanied by maximal transverse momentum.
- Possibility to restore PT phase by increasing loss: re-entrant PT-symmetric phase.
- Fragile or robust nature of the PT-symmetric phase depends upon the relevant energy scale.

Acknowledgements: Young Collaborators!

Mark Babbey (HS senior)
PRA 83, 030103(R) 2010.

Vaibhav, Harsha
(HS juniors)
PRA 84,
043826, 2011.





Jacob Barnett (13 yo)
PRA 84, 024103 2011.

The PT Symmeter

PT Symmetry articles and information

Home | Welcome | Introducing PT-Symmetry | In the field… | Conferences

FEB 5, '12 12:00 AM

PT Symmetry on 60 Minutes

AUTHOR dwh
CATEGORIES Uncategorized

An article on a young mathematical prodigy on the 60 minutes news programme on US television shows him working on PT Symmetry with Prof YN Joglekar at IUPUI.

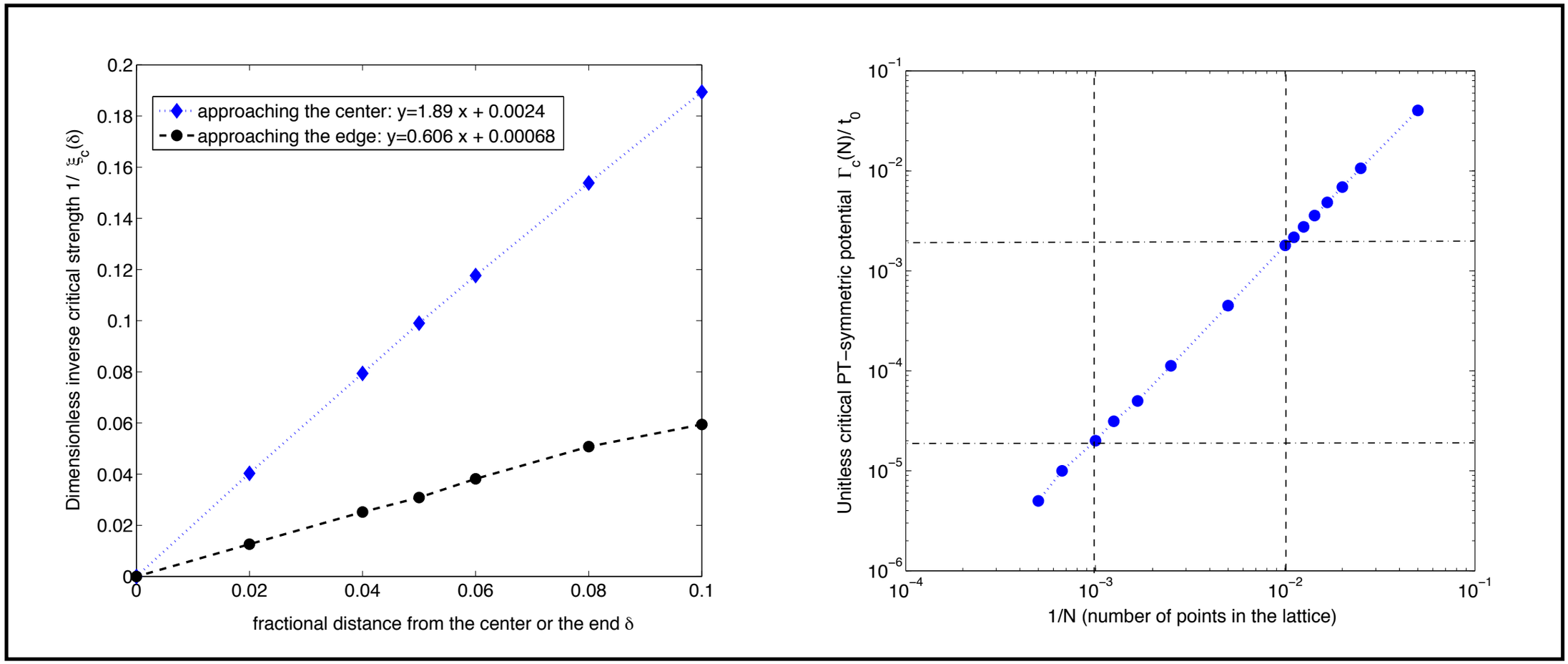
Their research article is available on arXiv at **http://arxiv.org/abs/1108.6083**, was published in Physical Review A (**http://pra.aps.org/abstract/PRA/v84/i2/e024103**), was reported on the PT-Symmeter (**http://ptsymmetry.net/?p=552**), and can now be seen as part of a documentary on the CBS 60 minutes website here:

http://www.cbsnews.com/video/watch/?id=7395214n&tag=re1.galleries

There is plenty of room at the bottom!

arXiv:1206.3310

Scaling results for lattice/continuum case



Finite continuum results = vanishing (fragile) lattice results.
Finite lattice results = diverging continuum results.