RGC Ref.: N_HKUST608/17
NSFC Ref. : 11761161002
(please insert ref. above)

The Research Grants Council of Hong Kong
NSFC/RGC Joint Research Scheme
Joint Completion Report

(Please attach a copy of the completion report submitted to the NSFC by the Mainland researcher)

Part A: The Project and Investigator(s)

1. Project Title

Manipulating Light Using Non-Hermitian Photonic Crystals: Theory and Experiment
非厄米光子晶體中光場調控理論與實驗研究

2. Investigator(s) and Academic Department/Units Involved

	Hong Kong Team	Mainland Team
Name of Principal Investigator *(with title)*	Prof CHAN Che Ting	Prof DONG Jian Wen
Post	Daniel CK Yu Professor of Science	Professor
Unit / Department / Institution	Department of Physics /HKUST	PHYSICS/SYSU
Contact Information	Email: phchan@ust.hk	Email: dongjwen@mail.sysu.edu.cn
Co-investigator(s) *(with title and institution)*	Dr CHEN Wen Jie * HKUST	Prof. CHEN Wen Jie * SYSU

*Wen Jie Chen was recruited by and joined SYSU in June 2018. He remained an active member of this collaboration.

3. Project Duration

	Original	Revised	Date of RGC/ Institution Approval *(must be quoted)*
Project Start date	01/01/2018		
Project Completion date	31/12/2021		
Duration *(in month)*	48		
Deadline for Submission of Completion Report	31/12/2022		

<u>Part B: The Completion Report</u>

5. Project Objectives

5.1 Objectives as per original application

1. Study the optical properties of non-Hermitian optical periodic structures (such as photonic crystals with gain and loss), including those with unbalanced gain/loss, those with parity-time symmetry, and those with differential loss.
2. Design and fabricate 2D and 3D photonic crystals that exhibit exceptional points, rings, and higher-dimension momentum space structures (such as tori and periodic minimal surfaces) of those singular points.

3. Measure and characterize the unusual optical properties of non-Hermitian photonic structures and explore their application potentials.

5.2 Revised Objectives

Date of approval from the RGC: N/A

Reasons for the change:

1.
2.
3. ....

6. Research Outcome

Major findings and research outcome
(maximum 1 page; please make reference to Part C where necessary)

Objective 1:
Exceptional points (EPs) and their coalescence of PT-symmetric interface states in photonic crystals: We demonstrated that the interface between two non-Hermitian photonic crystals with different signs of the imaginary parts of permittivity supports surface states with real eigenfrequencies. The dispersion of such interface states exhibits novel features such as zigzag trajectories or closed loops. *Anisotropic exceptional points of arbitrary order*: While most studies of non-Hermitian systems focus on ordered systems, we found that anisotropic EPs of arbitrary order are supported in non-Hermitian random systems with asymmetric hoppings. *Exceptional points make an Astroid in non-Hermitian Lieb lattice*: An astroid-shaped loop of EPs is found to spawn from the triple degeneracy point in the Brillouin zone of a non-Hermitian lattice and we discuss the experimental realization using coupled waveguide arrays. *Exceptional cones in 4D parameter space*: Non-Hermiticity is used as a synthetic parameter in PT-symmetric photonic crystals to study the topological physics in higher-dimension momentum space structures. *Interconversion of Exceptional Points between Different Orders in non-Hermitian Systems*: We showed that touching intersections of EP surfaces will increase the order of EPs while crossing intersection lowers the order of EPs.

Objective 2:
Realization of complex conjugate media using non-PT-symmetric photonic crystals: We showed that non-PT-symmetric photonic crystals can exhibit real spectra if the average non-Hermiticity strength within the unit cell for the eigenstates is zero. *Photonic Floquet media with a complex time-periodic permittivity*: We studied the formation of EPs in a photonic medium with a complex time-periodic permittivity and observed the so-called "k-gaps". Photonic crystal slabs of a finite thickness are non-Hermitian photonic systems, but some eigenstates can become non-radiative in some special configurations called bound states in the continuum (BICs). We designed such slabs with BICs. *Merging bound states in the continuum by harnessing higher-order topological charges:* We showed how to realize steerable BICs in momentum space. *Ways to achieve efficient non-local vortex beam generation:* We proposed new paradigms to improve the efficiency of non-local vortex beam generation using photonic crystal slabs carrying BICs.

Objective 3:
Observation of surface mode arcs associated with nodal surfaces in electromagnetic metacrystals: We fabricated and characterized a photonic crystal that carries nodal surface degeneracies and observed surface state arcs that support the robust unidirectional transport. *Angle-Resolved Thermal Emission Spectroscopy Characterization of Non-Hermitian Metacrystals*: We established angle-resolved thermal emission spectroscopy as a new method which can directly measure the dispersion of photonic crystals within the light cone. *On-Chip Integrated Exceptional-Surface Micro-laser*: Using the optical properties unique to non-Hermitian photonic systems, we demonstrated a robust on-chip integrated visible frequency microlaser with linewidth compression and threshold reduction. *Polarization Steering Edge States of Eigenmodes in Plasmonic Meta-arrays*: We fabricated non-Hermitian photonic meta-arrays and demonstrated the steering of edge modes.

Potential for further development of the research and the proposed course of action
(maximum half a page)

Non-Hermitian system is now a burgeoning research area. Photonic crystal is a nice platform to further explore the physics and applications in this area for many reasons, including the relative ease to incorporate and control gain/loss and engineer the symmetry. Here are a few possible routes for further studies. The topology of non-Hermitian photonic systems is worth pursuing. In Hermitian systems, the classification of topological phases and the bulk-boundary correspondence are well established. All these known results require significant revision when system becomes non-Hermitian. We are working on these issues now. Non-Hermitian systems can have the so-called skin-effect which makes the distinction between bulk and boundary modes difficult. In photonic crystals, skin-effect can arise if we break time-reversal symmetry and impose gain/loss at the same time. We are also working on these problems now. We have made some discoveries already in this project concerning higher order singularities in high dimensional parameter space, and this is a wide-open area for further exploration. We have explored using non-Hermitian photonic platforms to realize some applications (e.g. microlasers), and more applications can be explored including the use of high-Q states (such as BICs) for wave manipulation. We will write a new proposal to explore BICs.

7. The Layman's Summary

(describe <u>in layman's language</u> the nature, significance and value of the research project, in no more than 200 words)

Modern information transfer is enabled by photonics while information processing is mostly handled by electronics. Photonics is distinctly different from electronics because electronic systems are usually described by "Hermitian" (energy-conserving) physics, while photonics is usually "non-Hermitian", as energy can flow in and out of photonic systems. It makes the study of photonics more challenging. In this project, we showed that light can be controlled by "non-Hermitian" photonic systems in ways that cannot be realized in Hermitian crystals. One important consideration is the "exceptional point (EP)", at which a non-Hermitian crystal differs completely from a Hermitian system. We focused part of our effort on what happens to exceptional points when "order" and "dimensionality" increase due to the extra degrees of freedom allowed by non-Hermiticity. We showed that isolated EPs can concatenate and become higher-dimensional structures such as loops and hypersurfaces, with dispersions and singularities that are not possible in Hermitian systems. As the dispersion in momentum space determines how light travels, novel dispersions will enable new ways to control the flow or confinement of light, leading to new devices and applications such as micro-lasers and wave front manipulators. New methods to measure and characterize such photonic crystals were also developed.

<u>Part C: Research Output</u>

8. Peer-reviewed journal publication(s) arising <u>directly</u> from this research project

(Please attach a copy of each publication and/or the letter of acceptance if not yet submitted in the previous progress report(s). All listed publications must acknowledge RGC's funding support by quoting the specific grant reference.)

*Please fill in the following table for **each** publication.*

i. **The Latest Status of Publication**	**Published**	**Accepted but not yet published^**	**Under Review^**	**Under Preparation^** (optional)
	✓			

^ For not-yet-published publication, items (vi) to (xxvi) can be left blank if information is not yet available.

ii. **Author(s)** *(denote the corresponding author with an asterisk*)*	Yi-Xin Xiao, Zhao-Qing Zhang, Zhi Hong Hang, and C. T. Chan*		
iii. **Contact information of the corresponding author(s)**	Name	ORCID (if any)	Email
	C. T. Chan	0000-0002-9335-8110	phchan@ust.hk
iv. **Title (in published language)**	Anisotropic exceptional points of arbitrary order		
v. **Title in other language (if any)**			
vi. **Full name of journal/book**	Physical Review B		
vii. **Volume**	99		
viii. **Issue number**	24		
ix. **Pages**	241403-1 – 241403-6		
x. **Article Number**	241403		
xi. **Other necessary publishing details (if any)**			
xii. **Year of publication / Year of acceptance**	2019		
xiii. **Original language of the publication**	English		
xiv. **Publisher or equivalent**	American physical society		
xv. **Digital object identifier (DOI)**	10.1103/PhysRevB.99.241403		
xvi. **Abstract (as set out in the journal article)**	A pair of anisotropic exceptional points (EPs) of arbitrary order is found in a class of non-Hermitian random systems with asymmetric hoppings. Both eigenvalues and eigenvectors exhibit distinct behaviors when these anisotropic EPs are approached from two orthogonal directions in the parameter space. For an order-N anisotropic EP, the critical exponents ν of phase rigidity are (N−1)/2 and N−1, respectively. These exponents are universal within the class. The order-N anisotropic EPs split and trace out multiple ellipses of EPs of order 2 in the parameter space. For some particular configurations, all the EP ellipses coalesce and form a ring of EPs of order N. Crossover to the conventional order-N EPs with ν=(N−1)/N is discussed.		
xvii. **Open access status** *(Immediate open access / Embargoed open access / Non-open access)*	*Non-open access*		
xviii. **Embargo end date (month, year) (if any)**	*Not applicable*		
xix. **Accessible from the institutional repository** *(Yes or No)*	*Yes*		

xx. **Hyperlink to the publication (the link to institutional repository if preferred) (if any)**	https://journals.aps.org/prb/abstract/10.1103/PhysRevB.99.241403
xxi. **Other affordable means for access (if any)** *(Individual article purchase offered by the publisher / Access through the university libraries (on membership) / Contacting the corresponding author(s))*	*Contacting the corresponding author*
xxii. **Article Processing Charge (APC) for publishing the article in an open access journal*** *(Required / Not required / Not applicable)*	*Not applicable*
xxiii. **Total amount of associated APC* (in Hong Kong dollars, if any)**	*Not applicable*
xxiv. **Amount of associated APC paid by university* (or universities, in case it is borne by more than one university) (in Hong Kong dollars, if any)**	*Not applicable*
xxv. **Copyright retained by author(s)** *(Yes or No)*	*No*
xxvi. **Number(s) and jurisdiction(s) of the granted patents associated with the article (if any)**	*Not applicable*
xxvii. **Submitted to RGC (indicate the year ending of the relevant progress report)**	2019
xxviii. **Attached to this report** *(Yes or No)*	*No*
xxix. **Acknowledged the support of RGC** *(Yes or No)*	*Yes*

i. **The Latest Status of Publication**	**Published**	**Accepted but not yet published^**	**Under Review^**	**Under Preparation^** (optional)
	✓			
^ For not-yet-published publication, items (vi) to (xxvi) can be left blank if information is not yet available.				
ii. **Author(s)** *(denote the corresponding author with an asterisk*)*	Yi-Xin Xiao, Kun Ding, Ruo-Yang Zhang, Zhi Hong Hang, and C. T. Chan*			
iii. **Contact information of the corresponding author(s)**	Name	ORCID (if any)	Email	
	C. T. Chan	0000-0002-9335-8110	phchan@ust.hk	
iv. **Title (in published language)**	Exceptional points make an Astroid in non-Hermitian Lieb lattice: Evolution and topological protection			
v. **Title in other language (if any)**				
vi. **Full name of journal/book**	Physical Review B			
vii. **Volume**	102			
viii. **Issue number**	24			
ix. **Pages**	245144-1 – 245144-11			
x. **Article Number**	245144			

xi. **Other necessary publishing details (if any)**	
xii. **Year of publication / Year of acceptance**	2020
xiii. **Original language of the publication**	English
xiv. **Publisher or equivalent**	American physical society
xv. **Digital object identifier (DOI)**	10.1103/PhysRevB.102.245144
xvi. **Abstract (as set out in the journal article)**	An astroid-shaped loop of exceptional points (EPs), comprising four cusps, is found to spawn from the triple degeneracy point in the Brillouin zone (BZ) of a Lieb lattice with nearest-neighbor hoppings when non-Hermiticity is introduced. The occurrence of the EP loop is due to the realness of the discriminant which is guaranteed by the non-Hermitian chiral symmetry. The EPs at the four cusps involve the coalescence of three eigenstates, which is the combined result of the non-Hermitian chiral symmetry and mirror-T symmetry. The EP loop is exactly an astroid in the limit of an infinitesimal non-Hermiticity. The EP loop expands from the M point with increasing non-Hermiticity and splits into two EP loops at a critical non-Hermiticity. The further increase of non-Hermiticity contracts the two EP loops towards and finally to two EPs at the X and Y points in the BZ, accompanied by the emergence of Dirac-like cones. The two EPs vanish at a larger non-Hermiticity. The EP loop disappears and several discrete EPs are found to survive when next-nearest hoppings are introduced to break the non-Hermitian chiral symmetry. A topological invariant called the discriminant number is used to characterize their robustness against perturbations. Both discrete EPs and those on the EP loop(s) are found to show anisotropic asymptotic behaviors. Finally, the experimental realization of the Lieb lattice using a coupled waveguide array is discussed.
xvii. **Open access status** *(Immediate open access / Embargoed open access / Non-open access)*	*Non-open access*
xviii. **Embargo end date (month, year) (if any)**	*Not applicable*
xix. **Accessible from the institutional repository** *(Yes or No)*	*Yes*
xx. **Hyperlink to the publication (the link to institutional repository if preferred) (if any)**	https://journals.aps.org/prb/abstract/10.1103/PhysRevB.102.245144
xxi. **Other affordable means for access (if any)** *(Individual article purchase offered by the publisher / Access through the university libraries (on membership) / Contacting the corresponding author(s))*	*Contacting the corresponding author*
xxii. **Article Processing Charge (APC) for publishing the article in an open access journal*** *(Required / Not required / Not applicable)*	*Not applicable*

xxiii. **Total amount of associated APC* (in Hong Kong dollars, if any)**	*Not applicable*
xxiv. **Amount of associated APC paid by university* (or universities, in case it is borne by more than one university) (in Hong Kong dollars, if any)**	*Not applicable*
xxv. **Copyright retained by author(s)** *(Yes or No)*	*No*
xxvi. **Number(s) and jurisdiction(s) of the granted patents associated with the article (if any)**	*Not applicable*
xxvii. **Submitted to RGC (indicate the year ending of the relevant progress report)**	2021
xxviii. **Attached to this report** *(Yes or No)*	*Yes*
xxix. **Acknowledged the support of RGC** *(Yes or No)*	*Yes*

i. **The Latest Status of Publication**	**Published**	**Accepted but not yet published^**	**Under Review^**	**Under Preparation^** (optional)
			✓	
^ For not-yet-published publication, items (vi) to (xxvi) can be left blank if information is not yet available.				

ii. **Author(s)** *(denote the corresponding author with an asterisk*)*	Meng Kang, Li Mao, Shunping Zhang, Meng Xiao, Hongxing Xu and C. T. Chan*		
iii. **Contact information of the corresponding author(s)**	Name	ORCID (if any)	Email
	C. T. Chan	0000-0002-9335-8110	phchan@ust.hk
iv. **Title (in published language)**	Merging bound states in the continuum by harnessing higher-order topological charges		
v. **Title in other language (if any)**			
vi. **Full name of journal/book**			
vii. **Volume**			
viii. **Issue number**			
ix. **Pages**			
x. **Article Number**			
xi. **Other necessary publishing details (if any)**			
xii. **Year of publication / Year of acceptance**			
xiii. **Original language of the publication**	English		
xiv. **Publisher or equivalent**			
xv. **Digital object identifier (DOI)**			

xvi. **Abstract (as set out in the journal article)**	Bound states in the continuum (BICs) can confine light with a theoretically infinite Q factor. However, in practical on-chip resonators, scattering loss caused by inevitable fabrication imperfection leads to finite Q factors due to the coupling of BICs with nearby radiative states. Merging multiple BICs can improve the robustness of BICs against fabrication imperfection by improving the Q factors of nearby states over a broad wavevector range. To date, the studies of merging BICs have been limited to fundamental BICs with topological charges ±1. Here we show the unique advantages of higher-order BICs (those with higher-order topological charges) in constructing merging BICs. Merging multiple BICs with a higher-order BIC can further improve the Q factors compared with those involving only fundamental BICs. In addition, higher-order BICs offer great flexibility in realizing steerable off-Γ merging BICs. A higher-order BIC at Γcan split into a few off-Γfundamental BICs by reducing the system symmetry. The split BICs can then be tuned to merge with another BIC, e.g., an accidental BIC, at an off-Γ point. When the in-plane mirror symmetry is further broken, merging BICs become steerable in the reciprocal space. Merging BICs provide a paradigm to achieve robust ultrahigh-Q resonances, which are important in enhancing nonlinear and quantum effects and improving the performance of optoelectronic devices.
xvii. **Open access status** *(Immediate open access / Embargoed open access / Non-open access)*	
xviii. **Embargo end date (month, year) (if any)**	
xix. **Accessible from the institutional repository** *(Yes or No)*	
xx. **Hyperlink to the publication (the link to institutional repository if preferred) (if any)**	
xxi. **Other affordable means for access (if any)** *(Individual article purchase offered by the publisher / Access through the university libraries (on membership) / Contacting the corresponding author(s))*	*Contacting the corresponding author*
xxii. **Article Processing Charge (APC) for publishing the article in an open access journal*** *(Required / Not required / Not applicable)*	
xxiii. **Total amount of associated APC* (in Hong Kong dollars, if any)**	
xxiv. **Amount of associated APC paid by university* (or universities, in case it is borne by more than one university) (in Hong Kong dollars, if any)**	
xxv. **Copyright retained by author(s)** *(Yes or No)*	
xxvi. **Number(s) and jurisdiction(s) of the granted patents associated with the article (if any)**	
xxvii. **Submitted to RGC (indicate the year ending of the relevant progress report)**	2021

xxviii. **Attached to this report** *(Yes or No)*	Yes
xxix. **Acknowledged the support of RGC** *(Yes or No)*	Yes

i. **The Latest Status of Publication**	**Published**	**Accepted but not yet published^**	**Under Review^**	**Under Preparation^** (optional)
	✓			
^ For not-yet-published publication, items (vi) to (xxvi) can be left blank if information is not yet available.				

ii. **Author(s)** *(denote the corresponding author with an asterisk*)*	M. L. Chang, M. Xiao, J. W. Dong, and C. T. Chan*		
iii. **Contact information of the corresponding author(s)**	Name	ORCID (if any)	Email
	C. T. Chan	0000-0002-9335-8110	phchan@ust.hk
iv. **Title (in published language)**	Observation of surface mode arcs associated with nodal surfaces in electromagnetic metacrystals		
v. **Title in other language (if any)**			
vi. **Full name of journal/book**	Journal of the Optical Society of America B: Optical Physics		
vii. **Volume**	38		
viii. **Issue number**	10		
ix. **Pages**	2953-2959		
x. **Article Number**	N/A		
xi. **Other necessary publishing details (if any)**			
xii. **Year of publication / Year of acceptance**	2021		
xiii. **Original language of the publication**	English		
xiv. **Publisher or equivalent**	Optica Publishing Group		
xv. **Digital object identifier (DOI)**	10.1364/JOSAB.427904		
xvi. **Abstract (as set out in the journal article)**	In this article, we designed, fabricated, and characterized an electromagnetic metacrystal that topologically carries nontrivial nodal surface degeneracies. Compared with nodal surfaces observed in an acoustic system, the topological charge of the nodal surface in our system is compensated by charge-2 Weyl points, and we designed our system considering the rules of symmetry. To demonstrate the existence of the nodal surfaces and their topological properties, we have experimentally observed surface state arcs derived from helicoid sheets of surface states connecting the nodal surface with a charge-2Weyl point. The surface states support the robust unidirectional transport on the surface, and the nodal surface provides more degrees of freedom to engineer the dispersion of surface states. Our system offers a platform to explore this new class of gapless topological electromagnetic wave systems.		

xvii. **Open access status** *(Immediate open access / Embargoed open access / Non-open access)*	*Non-open access*
xviii. **Embargo end date (month, year) (if any)**	*Not applicable*
xix. **Accessible from the institutional repository** *(Yes or No)*	*Yes*
xx. **Hyperlink to the publication (the link to institutional repository if preferred) (if any)**	https://opg.optica.org/josab/fulltext.cfm?uri=josab-38-10-2953&id=459212
xxi. **Other affordable means for access (if any)** *(Individual article purchase offered by the publisher / Access through the university libraries (on membership) / Contacting the corresponding author(s))*	*Contacting the corresponding author*
xxii. **Article Processing Charge (APC) for publishing the article in an open access journal*** *(Required / Not required / Not applicable)*	Not applicable
xxiii. **Total amount of associated APC* (in Hong Kong dollars, if any)**	*Not applicable*
xxiv. **Amount of associated APC paid by university* (or universities, in case it is borne by more than one university) (in Hong Kong dollars, if any)**	*Not applicable*
xxv. **Copyright retained by author(s)** *(Yes or No)*	*No*
xxvi. **Number(s) and jurisdiction(s) of the granted patents associated with the article (if any)**	*Not applicable*
xxvii. **Submitted to RGC (indicate the year ending of the relevant progress report)**	2021
xxviii. **Attached to this report** *(Yes or No)*	*Yes*
xxix. **Acknowledged the support of RGC** *(Yes or No)*	*Yes*

i. **The Latest Status of Publication**	**Published**	**Accepted but not yet published^**	**Under Review^**	**Under Preparation^** (optional)
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^ For not-yet-published publication, items (vi) to (xxvi) can be left blank if information is not yet available.				

ii. **Author(s)** *(denote the corresponding author with an asterisk*)*	W. Z. Liu, L. Shi, J. Zi and C. T. Chan*		
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	W.-Z. Liu	0000-0002-6582-4161	wzliu@ust.hk
iv. **Title (in published language)**	Ways to achieve efficient non-local vortex beam generation		
v. **Title in other language (if any)**			
vi. **Full name of journal/book**	Nanophotonics		
vii. **Volume**	10		
viii. **Issue number**	17		
ix. **Pages**	4297-4304		

x. **Article Number**	20210342
xi. **Other necessary publishing details (if any)**	
xii. **Year of publication / Year of acceptance**	2021
xiii. **Original language of the publication**	English
xiv. **Publisher or equivalent**	De Gruyter
xv. **Digital object identifier (DOI)**	10.1515/nanoph-2021-0342
xvi. **Abstract (as set out in the journal article)**	Based on the insights into the phenomenon of bound states in the continuum, a novel approach utilizing the momentum-space polarization morphologies of periodic structures to generate vortex beams has been proposed. Such periodic structures modulate beams in a non-local way and require no precise alignment. However, the efficiency of such an approach has not been analyzed in detail, and the efficiency in previous realizations is far from optimized. Here, we analyze the factors affecting the efficiency of non-local vortex beam generation. We show that the maximal efficiency cannot exceed 25% if the periodic structure carries only singlet resonances. To go beyond this limit, we propose two approaches to improve the efficiency. We theoretically analyze the mechanisms and verify the approaches by full-wave simulations. Both of the approaches serve to improve the generation efficiency by several folds.
xvii. **Open access status** *(Immediate open access / Embargoed open access / Non-open access)*	*Immediate open access*
xviii. **Embargo end date (month, year) (if any)**	*Not applicable*
xix. **Accessible from the institutional repository** *(Yes or No)*	*Yes*
xx. **Hyperlink to the publication (the link to institutional repository if preferred) (if any)**	https://www.degruyter.com/document/doi/10.1515/nanoph-2021-0342/html?lang=en
xxi. **Other affordable means for access (if any)** *(Individual article purchase offered by the publisher / Access through the university libraries (on membership) / Contacting the corresponding author(s))*	*Contacting the corresponding authors*
xxii. **Article Processing Charge (APC) for publishing the article in an open access journal*** *(Required / Not required / Not applicable)*	*Waived*
xxiii. **Total amount of associated APC* (in Hong Kong dollars, if any)**	Not applicable
xxiv. **Amount of associated APC paid by university* (or universities, in case it is borne by more than one university) (in Hong Kong dollars, if any)**	Not applicable
xxv. **Copyright retained by author(s)** *(Yes or No)*	*No*
xxvi. **Number(s) and jurisdiction(s) of the granted patents associated with the article (if any)**	Not applicable

xxvii. **Submitted to RGC (indicate the year ending of the relevant progress report)**	2021
xxviii. **Attached to this report** *(Yes or No)*	*Yes*
xxix. **Acknowledged the support of RGC** *(Yes or No)*	*Yes*

i. **The Latest Status of Publication**	**Published**	**Accepted but not yet published^**	**Under Review^**	**Under Preparation^** (optional)
	✓			
^ For not-yet-published publication, items (vi) to (xxvi) can be left blank if information is not yet available.				
ii. **Author(s)** *(denote the corresponding author with an asterisk*)*	X. Cui, K. Ding, J. W., Dong, and C. T. Chan*			
iii. **Contact information of the corresponding author(s)**	Name	ORCID (if any)	Email	
	C. T. Chan	0000-0002-9335-8110	phchan@ust.hk	
iv. **Title (in published language)**	Realization of complex conjugate media using non-PT-symmetric photonic crystals			
v. **Title in other language (if any)**				
vi. **Full name of journal/book**	Nanophotonics			
vii. **Volume**	*9*			
viii. **Issue number**	1			
ix. **Pages**	195-203			
x. **Article Number**	N/A			
xi. **Other necessary publishing details (if any)**				
xii. **Year of publication / Year of acceptance**	2020			
xiii. **Original language of the publication**	English			
xiv. **Publisher or equivalent**	De Gruyter			
xv. **Digital object identifier (DOI)**	10.1515/nanoph-2019-0389			

xvi. **Abstract (as set out in the journal article)**	Although parity-time (PT)-symmetric systems can exhibit real spectra in the exact PT-symmetry regime, PT-symmetry is actually not a necessary condition for the real spectra. Here, we show that non-PT-symmetric photonic crystals (PCs) carrying Dirac-like cone dispersions can always exhibit real spectra as long as the average non-Hermiticity strength within the unit cell for the eigenstates is zero. By building a non-Hermitian Hamiltonian model, we find that the real spectra of the non-PT-symmetric system can be explained using the concept of pseudo-Hermiticity. We demonstrate using effective medium theories that, in the long-wavelength limit, such non-PT-symmetric PCs behave like the so-called complex conjugate medium (CCM) whose refractive index is real but whose permittivity and permeability are complex numbers. The real refractive index for this effective CCM is guaranteed by the real spectrum of the PCs, and the complex permittivity and permeability come from non-PT-symmetric loss-gain distributions. We show some interesting phenomena associated with CCM, such as the lasing effect.
xvii. **Open access status** *(Immediate open access / Embargoed open access / Non-open access)*	*Immediate open access*
xviii. **Embargo end date (month, year) (if any)**	Not applicable
xix. **Accessible from the institutional repository** *(Yes or No)*	*Yes*
xx. **Hyperlink to the publication (the link to institutional repository if preferred) (if any)**	https://www.degruyter.com/document/doi/10.1515/nanoph-2019-0389/html?lang=en
xxi. **Other affordable means for access (if any)** *(Individual article purchase offered by the publisher / Access through the university libraries (on membership) / Contacting the corresponding author(s))*	*Contacting the corresponding author(s))*
xxii. **Article Processing Charge (APC) for publishing the article in an open access journal*** *(Required / Not required / Not applicable)*	Required
xxiii. **Total amount of associated APC* (in Hong Kong dollars, if any)**	HK$17,169.75
xxiv. **Amount of associated APC paid by university* (or universities, in case it is borne by more than one university) (in Hong Kong dollars, if any)**	HK$17,169.75
xxv. **Copyright retained by author(s)** *(Yes or No)*	*No*
xxvi. **Number(s) and jurisdiction(s) of the granted patents associated with the article (if any)**	Not applicable
xxvii. **Submitted to RGC (indicate the year ending of the relevant progress report)**	2019
xxviii. **Attached to this report** *(Yes or No)*	*No*
xxix. **Acknowledged the support of RGC** *(Yes or No)*	*Yes*

i. **The Latest Status of Publication**	**Published**	**Accepted but not yet published^**	**Under Review^**	**Under Preparation^** (optional)
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^ For not-yet-published publication, items (vi) to (xxvi) can be left blank if information is not yet available.				
ii. **Author(s)** *(denote the corresponding author with an asterisk*)*	X. Cui, K. Ding, J. W., Dong, and C. T. Chan*			
iii. **Contact information of the corresponding author(s)**	Name	ORCID (if any)	Email	
	C. T. Chan	0000-0002-9335-8110	phchan@ust.hk	
iv. **Title (in published language)**	Exceptional points and their coalescence of PT-symmetric interface states in photonic crystals			
v. **Title in other language (if any)**				
vi. **Full name of journal/book**	Physical Review B			
vii. **Volume**	100			
viii. **Issue number**	11			
ix. **Pages**	115412-1 – 115412-15			
x. **Article Number**	115412			
xi. **Other necessary publishing details (if any)**				
xii. **Year of publication / Year of acceptance**	2019			
xiii. **Original language of the publication**	English			
xiv. **Publisher or equivalent**	American physical society			
xv. **Digital object identifier (DOI)**	10.1103/PhysRevB.100.115412			

xvi. **Abstract (as set out in the journal article)**	The existence of surface electromagnetic waves in the dielectric-metal interface is due to the sign change of real parts of permittivity across the interface. In this work, we demonstrate that the interface constructed by two semi-infinite photonic crystals with different signs of the imaginary parts of permittivity also supports surface electromagnetic eigenmodes with real eigenfrequencies, protected by PT symmetry of the loss-gain interface. Using a multiple scattering method and full wave numerical methods, we show that the dispersion of such interface states exhibit unusual features such as zigzag trajectories or closed-loops. To quantify the dispersion, we establish a nonHermitian Hamiltonian model that can account for the zigzag and closed-loop behavior for arbitrary Bloch momentums. The properties of the interface states near the Brillouin zone center can also be explained within the framework of effective medium theory. It is shown that turning points of the dispersion are exceptional points (EPs), which are characteristic features of non-Hermitian systems. When the permittivity of photonic crystal changes, these EPs can coalesce into higher order EPs or anisotropic EPs. These interface modes hence exhibit and exemplify many complex phenomena related to exceptional point physics.
xvii. **Open access status** *(Immediate open access / Embargoed open access / Non-open access)*	*Non-open access*
xviii. **Embargo end date (month, year) (if any)**	Not applicable
xix. **Accessible from the institutional repository** *(Yes or No)*	*Yes*
xx. **Hyperlink to the publication (the link to institutional repository if preferred) (if any)**	https://journals.aps.org/prb/abstract/10.1103/PhysRevB.100.115412
xxi. **Other affordable means for access (if any)** *(Individual article purchase offered by the publisher / Access through the university libraries (on membership) / Contacting the corresponding author(s))*	*Contacting the corresponding author*
xxii. **Article Processing Charge (APC) for publishing the article in an open access journal*** *(Required / Not required / Not applicable)*	*Not applicable*
xxiii. **Total amount of associated APC* (in Hong Kong dollars, if any)**	Not applicable
xxiv. **Amount of associated APC paid by university* (or universities, in case it is borne by more than one university) (in Hong Kong dollars, if any)**	Not applicable
xxv. **Copyright retained by author(s)** *(Yes or No)*	*No*
xxvi. **Number(s) and jurisdiction(s) of the granted patents associated with the article (if any)**	Not applicable

xxvii. **Submitted to RGC (indicate the year ending of the relevant progress report)**	2019
xxviii. **Attached to this report** *(Yes or No)*	*No*
xxix. **Acknowledged the support of RGC** *(Yes or No)*	*Yes*

i. **The Latest Status of Publication**	**Published**	**Accepted but not yet published^**	**Under Review^**	**Under Preparation^** (optional)
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^ For not-yet-published publication, items (vi) to (xxvi) can be left blank if information is not yet available.			
ii. **Author(s)** *(denote the corresponding author with an asterisk*)*	F. Zhong*, K. Ding, Y. Zhang, S. N. Zhu, C.T. Chan, and H. Liu*		
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iv. **Title (in published language)**	Angle-Resolved Thermal Emission Spectroscopy Characterization of Non-Hermitian Metacrystals		
v. **Title in other language (if any)**			
vi. **Full name of journal/book**	Physical Review Applied		
vii. **Volume**	13		
viii. **Issue number**	1		
ix. **Pages**	014071-1 – 014071-8		
x. **Article Number**	014071		
xi. **Other necessary publishing details (if any)**			
xii. **Year of publication / Year of acceptance**	2020		
xiii. **Original language of the publication**	English		
xiv. **Publisher or equivalent**	American physical society		
xv. **Digital object identifier (DOI)**	10.1103/PhysRevApplied.13.014071		

xvi. **Abstract (as set out in the journal article)**	We establish angle-resolved thermal emission spectroscopy as an alternative platform to characterize the intrinsic eigenmode properties of non-Hermitian systems. This method can directly map the dispersion of metacrystals within the light cone with high angular resolution. To illustrate its usefulness, we demonstrate the existence of bound states in the continuum (BICs) and non-Hermitian Fermi arcs in a planar corrugated metacrystal by measuring its angle-resolved thermal emission spectra. We show that a change in the thickness of the metacrystal can induce a band inversion between a BIC and a radiative state, and a pair of exceptional points emerge when the band inversion occurs. With this approach, the band mapping of non-Hermitian photonic systems can become a relatively straightforward task.
xvii. **Open access status** *(Immediate open access / Embargoed open access / Non-open access)*	*Non-open access*
xviii. **Embargo end date (month, year) (if any)**	Not applicable
xix. **Accessible from the institutional repository** *(Yes or No)*	*Yes*
xx. **Hyperlink to the publication (the link to institutional repository if preferred) (if any)**	https://journals.aps.org/prapplied/abstract/10.1103/PhysRevApplied.13.014071
xxi. **Other affordable means for access (if any)** *(Individual article purchase offered by the publisher / Access through the university libraries (on membership) / Contacting the corresponding author(s))*	*Contacting the corresponding author(s))*
xxii. **Article Processing Charge (APC) for publishing the article in an open access journal*** *(Required / Not required / Not applicable)*	*Not applicable*
xxiii. **Total amount of associated APC* (in Hong Kong dollars, if any)**	Not applicable
xxiv. **Amount of associated APC paid by university* (or universities, in case it is borne by more than one university) (in Hong Kong dollars, if any)**	Not applicable
xxv. **Copyright retained by author(s)** *(Yes or No)*	*No*
xxvi. **Number(s) and jurisdiction(s) of the granted patents associated with the article (if any)**	Not applicable
xxvii. **Submitted to RGC (indicate the year ending of the relevant progress report)**	2021
xxviii. **Attached to this report** *(Yes or No)*	*Yes*
xxix. **Acknowledged the support of RGC** *(Yes or No)*	*Yes*

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<tr><td rowspan="2">i. The Latest Status of Publication</td><td>Published</td><td>Accepted but not yet published^</td><td>Under Review^</td><td>Under Preparation^ (optional)</td></tr>
<tr><td>✓</td><td></td><td></td><td></td></tr>
<tr><td colspan="5">^ For not-yet-published publication, items (vi) to (xxvi) can be left blank if information is not yet available.</td></tr>
<tr><td>ii. Author(s)
(denote the corresponding author with an asterisk*)</td><td colspan="4">N. Wang, Z. Q. Zhang, and C. T. Chan*</td></tr>
<tr><td rowspan="2">iii. Contact information of the corresponding author(s)</td><td>Name</td><td colspan="2">ORCID (if any)</td><td>Email</td></tr>
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<tr><td>iv. Title (in published language)</td><td colspan="4">Photonic Floquet media with a complex time-periodic permittivity</td></tr>
<tr><td>v. Title in other language (if any)</td><td colspan="4"></td></tr>
<tr><td>vi. Full name of journal/book</td><td colspan="4">Physical Review B</td></tr>
<tr><td>vii. Volume</td><td colspan="4">98</td></tr>
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<tr><td>xiv. Publisher or equivalent</td><td colspan="4">American physical society</td></tr>
<tr><td>xv. Digital object identifier (DOI)</td><td colspan="4">10.1103/PhysRevB.98.085142</td></tr>
</table>

xvi. **Abstract (as set out in the journal article)**	We study the formation of exceptional points (EPs) in a photonic medium with a complex time-periodic permittivity, i.e., ε(t)=εo+εrsin(Ωt). We formulate Maxwell's equations in the form of a first-order non-Hermitian Floquet Hamiltonian matrix and solve it analytically for the Floquet band structures. In the case when εr is real, to the first order in εr, the band structures show a phase transition from an exact phase with real quasienergies to a broken phase with complex quasienergies inside a region of wave-vector space, the so-called k gap. We show that the two EPs at the upper and lower edges of the k gap have opposite chiralities in the stroboscopic sense. By picking up the mode with a positive imaginary quasienergy, the wave propagation inside the k gap can grow exponentially. In three dimensions, such pairs of EPs span two concentric spherical surfaces in the k space and repeat themselves periodically in the quasienergy space with Ω as the period. However, in the case when εr is purely imaginary, the k gap disappears and gaps in the quasienergy space are opened. Our analytical results agree well with finite-difference time domain simulations. To second order in εr, additional EP pairs are found for both the cases of real and imaginary εr. We also extend our theory to the case where the permittivity is simultaneously modulated in both space and time, i.e., ε(x,t)=εo+εrsin(Ωt−βx+ϕ). For a real εr, we find that EPs also exist when the modulation speed cm=Ω/β is faster than the speed of the wave travelling inside the medium.
xvii. **Open access status** *(Immediate open access / Embargoed open access / Non-open access)*	*Non-open access*
xviii. **Embargo end date (month, year) (if any)**	Not applicable
xix. **Accessible from the institutional repository** *(Yes or No)*	*Yes*
xx. **Hyperlink to the publication (the link to institutional repository if preferred) (if any)**	https://journals.aps.org/prb/abstract/10.1103/PhysRevB.98.085142
xxi. **Other affordable means for access (if any)** *(Individual article purchase offered by the publisher / Access through the university libraries (on membership) / Contacting the corresponding author(s))*	*Contacting the corresponding author*
xxii. **Article Processing Charge (APC) for publishing the article in an open access journal*** *(Required / Not required / Not applicable)*	*Not applicable*
xxiii. **Total amount of associated APC* (in Hong Kong dollars, if any)**	Not applicable
xxiv. **Amount of associated APC paid by university* (or universities, in case it is borne by more than one university) (in Hong Kong dollars, if any)**	Not applicable

xxv. **Copyright retained by author(s)** *(Yes or No)*	*No*
xxvi. **Number(s) and jurisdiction(s) of the granted patents associated with the article (if any)**	Not applicable
xxvii. **Submitted to RGC (indicate the year ending of the relevant progress report)**	2019
xxviii. **Attached to this report** *(Yes or No)*	*No*
xxix. **Acknowledged the support of RGC** *(Yes or No)*	*Yes*

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ii. **Author(s)** *(denote the corresponding author with an asterisk*)*	Q. Wang, K. Ding, H. Liu*, S. N. Zhu, and C. T. Chan*			
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iv. **Title (in published language)**	Exceptional cones in 4D parameter space			
v. **Title in other language (if any)**				
vi. **Full name of journal/book**	Optics Express			
vii. **Volume**	28			
viii. **Issue number**	2			
ix. **Pages**	1758-1770			
x. **Article Number**	N/A			
xi. **Other necessary publishing details (if any)**				
xii. **Year of publication / Year of acceptance**	2020			
xiii. **Original language of the publication**	English			
xiv. **Publisher or equivalent**	Optica Publishing Group			
xv. **Digital object identifier (DOI)**	10.1364/OE.381700			

xvi. **Abstract (as set out in the journal article)**	The notion of synthetic dimensions has expanded the realm of topological physics to four dimensional (4D) space lately. In this work, non-Hermiticity is used as a synthetic parameter in PT-symmetric photonic crystals to study the topological physics in 4D non-Hermitian synthetic parameter space. We realize a 3D exceptional hypersurface (EHS) in such 4D parameter space, and the degeneracy points emerge due to the symmetry of synthetic parameters. We further demonstrate the existence of exceptional degenerate points (EDPs) on the EHS that originates from the chirality of exceptional points (EPs), and the exceptional surface near EDPs behaves like a Dirac cone. We further show that a very narrow reflection plateau can be found near these EDPs, and their sensitivity towards the PT-symmetry breaking environmental perturbation can make these degeneracy points useful in optical sensing and many other nonlinear and quantum optical applications.
xvii. **Open access status** *(Immediate open access / Embargoed open access / Non-open access)*	*Immediate open access*
xviii. **Embargo end date (month, year) (if any)**	Not applicable
xix. **Accessible from the institutional repository** *(Yes or No)*	*Yes*
xx. **Hyperlink to the publication (the link to institutional repository if preferred) (if any)**	https://opg.optica.org/oe/fulltext.cfm?uri=oe-28-2-1758&id=425913
xxi. **Other affordable means for access (if any)** *(Individual article purchase offered by the publisher / Access through the university libraries (on membership) / Contacting the corresponding author(s))*	*Contacting the corresponding authors*
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xxiii. **Total amount of associated APC* (in Hong Kong dollars, if any)**	Not applicable
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xxv. **Copyright retained by author(s)** *(Yes or No)*	*No*
xxvi. **Number(s) and jurisdiction(s) of the granted patents associated with the article (if any)**	Not applicable
xxvii. **Submitted to RGC (indicate the year ending of the relevant progress report)**	2019
xxviii. **Attached to this report** *(Yes or No)*	*No*
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i. **The Latest Status of Publication**	**Published**	**Accepted but not yet published^**	**Under Review^**	**Under Preparation^** (optional)
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ii. **Author(s)** *(denote the corresponding author with an asterisk*)*	K. Liao, Y. G. Zhong, Z. C. Du, G. D. Liu, C. T. Li, X. Xi Wu, C. H. Deng, C. C. Lu, X. Y. Wang, C. T. Chan*, Q. H. Song*, S. F. Wang*, X. F. Liu*, X. Y. Hu*, Q. H. Gong		
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iv. **Title (in published language)**	On-Chip Integrated Exceptional-Surface Microlaser		
v. **Title in other language (if any)**			
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xii. **Year of publication / Year of acceptance**			
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xiv. **Publisher or equivalent**			
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xvi. **Abstract (as set out in the journal article)**	High-speed visible-light communication and information-processing systems have a substantial application potential, benefiting from huge bandwidth resources. An on-chip integrated visible microlaser is a core unit of such systems and needs robustness against fabrication errors, a compressible linewidth, a reducible threshold, and in-plane emission (output light directly entering signal waveguides and photonic circuits). However, until now, it is still a great challenge to meet these requirements simultaneously. Here, we report a scalable strategy of mode clipping to realize a robust on-chip integrated visible microlaser with linewidth compression induced by coherent coupling and threshold reduction facilitated by unidirectional emission on exceptional surfaces of different orders (n). The degree of linewidth compression (the linewidth ratio between an exceptional-surface-tailored microlaser and a control system with a symmetrically placed modulation waveguide) is proportional to $\sqrt{\sqrt[n]{2}-1}$. In addition, the degree of improved energy-conversion efficiency (the ratio of the growth rate of the microlaser intensity with increasing pump light intensity between the proposed microlaser and the control system) is proportional to n. We experimentally demonstrated an on-chip integrated second-order exceptional-surface-tailored microlaser with a lasing linewidth of 0.8 nm and a pump threshold of 2.4 μJ/cm2, which are decreased to 67% and 44%, respectively, compared with those of the control system. The emitted light is coupled to the signal waveguide, facilitating subsequent signal processing in photonic circuits, and the microlaser performs well under different configuration parameters. We further prove the potential application of this strategy by demonstrating an exceptional-surface-tailored topological microlaser with a unique performance. This work lays a foundation for further development of on-chip integrated high-speed visible-light communication and processing systems. Moreover, it provides a platform for the fundamental study of non-Hermitian photonics, opening new research directions for non-Hermitian photonics with nonlinear optics and topological photonics.
xvii. **Open access status** *(Immediate open access / Embargoed open access / Non-open access)*	
xviii. **Embargo end date (month, year) (if any)**	

xix. **Accessible from the institutional repository** *(Yes or No)*	
xx. **Hyperlink to the publication (the link to institutional repository if preferred) (if any)**	
xxi. **Other affordable means for access (if any)** *(Individual article purchase offered by the publisher / Access through the university libraries (on membership) / Contacting the corresponding author(s))*	
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xxvi. **Number(s) and jurisdiction(s) of the granted patents associated with the article (if any)**	
xxvii. **Submitted to RGC (indicate the year ending of the relevant progress report)**	2021
xxviii. **Attached to this report** *(Yes or No)*	*Yes*
xxix. **Acknowledged the support of RGC** *(Yes or No)*	*Yes*

i. **The Latest Status of Publication**	**Published**	**Accepted but not yet published^**	**Under Review^**	**Under Preparation^** (optional)
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ii. **Author(s)** *(denote the corresponding author with an asterisk*)*	Q. C. Yan, E. Cao, X. Y. Hu*, Z. C. Du, Y. T. Ao, S. S. Chu, Q. Sun, X. Shi, C. T. Chan*, Q. H. Gong, H. Misawa*			
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	H. Misawa	0000-0003-1070-387X	misawa@es.hokudai.ac.jp	
iv. **Title (in published language)**	Edge States in Plasmonic Meta-Arrays			
v. **Title in other language (if any)**				
vi. **Full name of journal/book**				
vii. **Volume**				
viii. **Issue number**				
ix. **Pages**				
x. **Article Number**				
xi. **Other necessary publishing details (if any)**				

xii. **Year of publication / Year of acceptance**	
xiii. **Original language of the publication**	
xiv. **Publisher or equivalent**	
xv. **Digital object identifier (DOI)**	
xvi. **Abstract (as set out in the journal article)**	Photonic edge states provide a novel platform to control and enhance light-matter interactions. Recently, it became increasing popular to generate such localized states using the bulk-edge correspondence of topological photonic crystals. While the topological approach is elegant, the design and fabrication of these complex photonic topological crystals is tedious. Here, we report a simple and effective strategy to construct and steer photonic edge state in a simple plasmonic meta-array which is easy to design and fabricate. The meta-array is a compact structure that just requires a small number of plasmonic particles to form a simple lattice. To demonstrate the idea, meta-arrays with a square-lattice configuration are fabricated and measured by using an ultrahigh spatial resolution photoemission electron microscopy. The existence of edge states depends on the geometric details such as the row and column number of the lattice, as well as the gap distance between the particles. Plasmonic meta-arrays with different lattice configurations, including square, triangular, and honeycomb, can all support edge state. Moreover, numerical simulations show that the excited edge states can be used for the generation of the quantum entanglement. This work not only provides a new platform for the study of nanoscale photonic devices, but also open a new way for the fundamental study of nanophotonics based on edge states.
xvii. **Open access status** *(Immediate open access / Embargoed open access / Non-open access)*	
xviii. **Embargo end date (month, year) (if any)**	
xix. **Accessible from the institutional repository** *(Yes or No)*	
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xxvii. **Submitted to RGC (indicate the year ending of the relevant progress report)**	2021
xxviii. **Attached to this report** *(Yes or No)*	*Yes*
xxix. **Acknowledged the support of RGC** *(Yes or No)*	*Yes*

i. **The Latest Status of Publication**	**Published**	**Accepted but not yet published^**	**Under Review^**	**Under Preparation^** (optional)
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^ For not-yet-published publication, items (vi) to (xxvi) can be left blank if information is not yet available.				
ii. **Author(s)** *(denote the corresponding author with an asterisk*)*	H. F. Wang, Y. X. Xiao, Z. Q. Zhang, C. T. Chan*, D. Y. Lei*			
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	D.Y. Lei	0000-0002-8963-0193	dangylei@cityu.edu.hk	
iv. **Title (in published language)**	Interconversion of Exceptional Points between Different Orders in non-Hermitian Systems			
v. **Title in other language (if any)**				
vi. **Full name of journal/book**				
vii. **Volume**				
viii. **Issue number**				
ix. **Pages**				
x. **Article Number**				
xi. **Other necessary publishing details (if any)**				
xii. **Year of publication / Year of acceptance**				
xiii. **Original language of the publication**				
xiv. **Publisher or equivalent**				
xv. **Digital object identifier (DOI)**				

xvi. **Abstract (as set out in the journal article)**	Singularities of non-Hermitian systems typified by exceptional points (EPs) play a pivotal role in understanding non-Hermitian topological phases and possess many intriguing physical properties. Here, in a generic four-level non-Hermitian system supporting EPs of order four (EP4s) and two types of EP2s, we study the interconversion between EPs of different orders by examining both the eigenvalues and eigenvectors. We show analytically that all EP4s in the system are formed at the touching intersections of two hypersurfaces of EP2s. Contrarily, the crossing intersection of curves of EPs lowers the order of EPs. We believe the mechanisms of both upward and downward conversions (the increase and decrease of defectiveness) discovered here can be generalized to other non-Hermitian systems and EPs of any order. Our work provides a deeper and global understanding of EPs and may inspire advanced applications with richer phenomena and functionalities.
xvii. **Open access status** *(Immediate open access / Embargoed open access / Non-open access)*	
xviii. **Embargo end date (month, year) (if any)**	
xix. **Accessible from the institutional repository** *(Yes or No)*	
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xxvi. **Number(s) and jurisdiction(s) of the granted patents associated with the article (if any)**	
xxvii. **Submitted to RGC (indicate the year ending of the relevant progress report)**	2021
xxviii. **Attached to this report** *(Yes or No)*	*Yes*
xxix. **Acknowledged the support of RGC** *(Yes or No)*	*Yes*

* *This information will be for the Secretariat's reference only and not be disclosed to the public.*

9. Recognized international conference(s) in which paper(s) related to this research project was/were delivered *(Please attach a copy of each delivered paper. All listed papers must acknowledge RGC's funding support by quoting the specific grant reference.)*

Month/Year / Place	Title	Conference Name	Submitted to RGC *(indicate the year ending of the relevant progress report)*	Attached to this report *(Yes or No)*	Acknowledged the support of this Joint Research Scheme *(Yes or No)*	Accessible from the institutional repository *(Yes or No)*
04/2022 online	Topological Properties of Boundary Condition-sensitive Systems [keynote]	PIERS 2022	2021	*Yes*	*Yes, verbally*	*No*
09/2021 online	Exceptional arcs and cusps	Metamaterials 2021 (The 15th International Congress on Artificial Materials for Novel Wave Phenomena)	2021	*Yes*	*Yes ,verbally*	*No*
08/2020 Online	Anisotropic exceptional points of arbitrary order and exceptional ellipses	SPIE Nanoscience + Engineering	2021	*Yes*	*Yes, verbally*	*No*
07/2019 Lisbon	Anisotropic exceptional points of arbitrary order [invited talk]	META 2019 (the 10th International Conference on Metamaterials, Photonic Crystals and Plasmonics)	2019	*Yes*	*Yes, verbally*	*No*
12/2019 Xiamen	Anisotropic exceptional points of arbitrary order	Progress in Electromagnetic Research Symposium	2019	*Yes*	*Yes, verbally*	*No*
03/2018 Los Angeles	Realization of complex conjugate medium by using a ring of exceptional points in non-PT-symmetric photonic crystals	APS March Meeting	2019	*Yes*	*Yes, verbally*	*No*
10/ 2018, Xi'an	A New Generation of Photonic Crystals [keynote talk]	AOM 2018	2019	*Yes*	*Yes, verbally*	*No*

10. Student(s) trained *(Please attach a copy of the title page of the thesis.)*

Name	Degree registered for	Date of registration	Date of thesis submission/ graduation
Xiao Han Cui	PhD	2014-08-17	2019-07-22
Mingli Chang	PhD	2014-09-01	2021-08-18

11. Other impact *(e.g. award of patents or prizes, collaboration with other research institutions, technology transfer, etc.),*

Wen Jie Chen received the Thousand Talents for Young Scholars award. We have collaborated with Fudan University, Nanjing University and Peking University.

12. Statistics on Research Outputs *(Please ensure the summary statistics below are consistent with the information presented in other parts of this report.)*

	Peer-reviewed journal publications	Conference papers	Scholarly books, monographs and chapters	Patents awarded	Other research outputs (Please specify)
No. of outputs arising directly from this research project [or conference]	Published – 9, under review – 4	7	0	0	0