

## Education

## Nanjing University

College of Engineering and Applied Sciences

Nanjing, Jiangsu

Doctor of Philosophy

Optical Engineering

Q.E. – Top 15%

Nonlinear Fourier Optics

– 2025.06

Dissertation:

“Analytic 3D vector linear non-uniform & nonlinear Fourier crystal optics in arbitrary  $\bar{\epsilon}$ ,  $\bar{\chi}$  dielectrics”

Master's Studies

Quantum Electronics

Courses Score – 93.5

THz OAM Source

– 2022.06

## Northeastern University

School of Physics, College of Science

Shenyang, Liaoning

Bachelor of Science

Applied Physics

GPA Rank – 1/400

DDTank Aimbots

– 2020.06

Thesis:

“Research &amp; design of nonlinear holography based on lithium niobate 3D nonlinear photonic crystal”



Freshman in College

Science

Sichuan Prov. – Top 2%

3 e-books with C++

2016.09 –

## Research Projects

Vector Nonlinear  
Fourier Crystal Optics

Solving

$$[(\nabla \times)^2 - k_0^2 \bar{\epsilon} \cdot] \mathbf{E}(\mathbf{r}) = k_0^2 \bar{\chi} : \mathcal{F}_\omega^{-1} [\tilde{\mathbf{E}}_p \tilde{\mathbf{E}}_p](\mathbf{r})$$
 analytically

2023.05 –

- First & fastest white box solver ever for this inhomogeneous  $\mathbb{C}^3(\mathbb{R}^3)$  wave equation
  - or other similar equations, with unprecedented efficiency-accuracy product
- No competitors for the time being: other methods or software including
  - k-space RK4, pseudo-spectral, SSF, Green's Function methods, FDTD, COMSOL...
- Reproduced well-known papers, all of which provide either zero or wrong theory:
  - [Nat.Photo.](#) #proven theoretically wrong by this project #femtosecond pump
  - [O.E.](#) #Bloembergen's legacy2 #experiment | [O.M.E.](#) #z-component
  - [O.E.](#) | [Q.E.](#) #high N.A. # $\bar{\chi}$  anisotropy

decks [1](#) [2](#) [3](#) ... Complex Vector Linear  
Fourier Crystal Optics

Analytic

$$\mathbf{E}(\mathbf{r}) \in \mathbb{C}^3(\mathbb{R}^3) \text{ to } [(\nabla \times)^2 - k_0^2 \bar{\epsilon} \cdot] \mathbf{E}(\mathbf{r}) = \mathbf{0} \text{ where } \epsilon_{ij} \in \mathbb{C}$$

2023.02 –

- Drawing insights from [PRS.A.](#) #M.V.Berry's legacy | [A.O.P.](#) | [A.P.B.](#) | [J.QSRT.](#)
- Next generation will come really close to the exact solution with highly Hermitian  $\bar{\epsilon}$
- Reproduced well-known papers, some are purely experimental (too hard to model):
  - [J.O.S.A.](#) #Bloembergen's legacy1 | [J.O.](#) | [O.M.](#) | [O.M.](#) | [J.O.](#) | [L.P.R.](#)
  - [JOSA.A.](#) | [O.E.](#) #tightly focus # $\bar{\epsilon}$  anisotropy | [Light.Sci.App.](#) | [O.E.](#)

decks [1](#) [2](#) [3](#) ... Real Scalar Nonlinear  
Fourier Crystal Optics

Closed-form

$$\mathbf{E}_3(\mathbf{r}) \in \mathbb{C}(\mathbb{R}^3) \text{ in } [\nabla^2 + k_3^2] \mathbf{E}_3(\mathbf{r}) = -k_{03}^2 \chi(\mathbf{r}) E_1(\mathbf{r}) E_2(\mathbf{r})$$

2022.02 –

- Solving this multivariable/field nonlinear convolution equation on my own
- Strong alternative to Green's Function, pseudo-spectral, split-step Fourier methods
- Reproduced well-known papers & models with maximum accuracy & efficiency:
  - [P.R.L.](#) #Green | [P.R.L.](#) #experiment #quantum | [P.R.L.](#) #experiment #scatter | [P.R.L.](#)
  - [L.P.R.](#) #SSF #quantum | [Matlab](#) #RCWA | [A.P.L.](#) #femtosecond pump
  - [O.L.](#) | [P.R.A.](#)

decks [1](#) [2](#) [3](#) [4](#) ...

## Scientific Activities

- [3] **The 4th Nanjing University Doctoral Interdisciplinary Innovation Forum** Nanjing, Jiangsu  
*"Analytic vector linear & nonlinear Fourier crystal optics in arbitrary  $\bar{\epsilon}$ ,  $\bar{\chi}$  dielectrics"* | Talk [slides] 2024.05.30
- [2] **2023 CSOE-NJU<sup>1</sup> Book Club Meeting & Sharing Session** Nanjing, Jiangsu  
*"A guided tour to Ray & Wave Optics Simulation"* | Talk [slides] 2023.12.09
- [1] **Academic Café Salon of the Research Group** Nanjing, Jiangsu  
*"Bi-directional notes on Nonlinear Optics in a roam-like app: RoamEdit"* | Talk [\*.pdf] 2021.05.21

## Publications

- [2] P. Chen, X. Xu, T. Wang, C. Zhou, D. Wei, J. Ma, J. Guo, X. Cui, X. Cheng, **C. Xie**, S. Zhang, S. Zhu, M. Xiao, and Y. Zhang, *Laser nanoprinting of 3D nonlinear holograms beyond 25000 pixels-per-inch for inter-wavelength-band information processing*, Nature Communications **14**, 5523 (2023)
- [1] J. Guo, Y. Zhang, H. Ye, L. Wang, P. Chen, D. Mao, **C. Xie**, Z. Chen, X. Wu, M. Xiao, and Y. Zhang, *Spatially Structured-Mode Multiplexing Holography for High-Capacity Security Encryption*, ACS Photonics **10**, 757–763 (2023)

## Academic Focus

<b>Next generation</b> high N.A. 3D vector non-uniform analytic linear & nonlinear Fourier crystal optics	2024.06 –
!Paraxial $k_0^\omega$ <b>High N.A.</b> 3D vector non-uniform analytic linear & nonlinear Fourier crystal optics	2024.03 –
Emphasizing $G_{xyz}^\omega$ <b>3D</b> vector non-uniform analytic linear & nonlinear Fourier crystal optics	2023.12 –
Involving $\bar{\chi}_\omega^{(2)}$ anisotropy <b>Vector</b> non-uniform analytic linear & nonlinear Fourier crystal optics	2023.06 –
!Unitary $G_\omega^\pm \Leftarrow$ !Hermitian $\bar{\epsilon}_r^\omega \Rightarrow$ <b>Non-uniform</b> analytic linear & nonlinear Fourier crystal optics	2023.03 –
Solution $E_\omega^\pm$ to $(\nabla^2 + k_{\omega\pm}^2)E_\omega^\pm \propto P_{\omega\pm}^{(2)}$ <b>Analytic</b> linear & nonlinear Fourier crystal optics	2022.09 –
Solution $\mathcal{F}[E_3] = \mathcal{F}[f(\mathcal{F}^{-1}[\cdot])]$ to the Eq. below <b>Nonlinear</b> angular spectrum theory for SFG	2022.06 –
Solution $\mathcal{F}[E_3] = \iiint f \cdot$ to $(\nabla^2 + k_3^2)E_3(r) \propto P_3^{(2)}(r)$ <b>Nonlinear</b> convolution solution to SFG	2022.03 –
Nonlinear THz LiNbO <sub>3</sub> -based metasurface	Quit THz project formally   COMSOL – 2022.01
BWOPO + THz optical parametric amplification	Mathematica   BookxNote Pro – 2021.12
THz backward optical parametric oscillator (BWOPO)	Mathematica   VBA Excel – 2021.11
Multi-cycle THz orbital angular momentum (OAM) source	RoamEdit   Blender – 2021.11
Narrow-band THz OAM source via Optical Rectification (OR)	Python   Blender – 2021.10
Electricity $\xrightarrow{\text{produce}}$ Acoustics $\xrightarrow{\text{modulate}}$ Optics	RoamEdit   VBA Excel – 2021.07
Visible Photons $\xrightarrow{\text{SPDC}}$ THz Spectroscopy	BookxNote Pro   GeoGebra   VBA Excel – 2021.06
Cavity Phase Matching = Sheet OPO	Paint 3D   RoamEdit   GeoGebra   VBA Excel – 2021.05
THz Holography via Optical Rectification	Matlab   GeoGebra   VBA Excel – 2021.01
Femtosecond laser $\xrightarrow{\text{Optical Rectification}}$ Terahertz (THz)	GeoGebra   VBA Excel – 2020.12
Multicycle THz pulse generation by OR in LiNbO <sub>3</sub> ... crystals	VBA PowerPoint – 2020.10

<sup>1</sup>The Nanjing University student branch of the Chinese Society for Optical Engineering







Honors & Awards

Academia	Doctoral Interdisciplinary Forum (Oral)	2nd place		¥500	Nanjing	U.	2024.05
	Doctor's Qualification Exam (Oral)	Excellent		Top 15%	Nanjing	U.	2024.01
	Bachelor Thesis & Defense	Excellent		1/90	Northeastern	U.	2020.06
Competition	Three Provinces Achievement Expo	Exhibition		Leader	Three	Prov.	2019.10
	"Challenge Cup" Tech Competition	Grand prize		Leader	Liaoning	Prov.	2019.06
Scholarships & Fellowships	Academic Fellowship	1st class		¥40,000	Nanjing	U.	2020-24
	"Jinchuan" Scholarship	1st place		¥5,000	Northeastern	U.	2019.04
	Academic Scholarship	1st place		¥2,000	Northeastern	U.	2018.06
	Entrance Scholarship	3rd place		¥5,000	Leshan No.1	H.S.	2013.09
Honors & Titles	Graduation with Honor	Outstanding			Northeastern	U.	2020.07
	League Member	Excellent			Northeastern	U.	2019.11
	Undergraduate Student	Excellent			Northeastern	U.	2018.12
Memberships	Chinese Society for Optical Engineering	Member			Nanjing	U.	2021-25
	"Qian Sanqiang" Talent Class	Head			I.H.E.P.		2017-20

Personal Projects

Behind NLAST <sup>2</sup>	0 → 1 : Techniques crafted from scratch in my acedemic project : NLAST	2022.02 –
	<ul style="list-style-type: none"><li>Managed to realize <i>tree</i>-print feature in CMD lines without knowing <i>any tree</i>-packages<ul style="list-style-type: none"><li>in order to visualize run-time <i>Call Stack</i> with <i>buried checkpoints</i> &amp; display <i>crucial info</i></li><li>to understand the <i>hierarchical structure</i> of my code from a more <i>abstract</i> perspective</li></ul></li><li>Enabled <i>multi-threads</i> to accelerate <i>for loops</i> in python while preserving the <i>loops'</i> order<ul style="list-style-type: none"><li>Implemented through utilizing the <i>producer-consumer model</i> (producer = thread pool)</li><li>Allow users to select which parts of the codes in the <i>for loops</i> to <i>parallelize</i> in CPU</li><li>Transform <i>multi-layer for loops</i> into <i>nested multi-threads</i>: each thread = a new thread pool</li><li>Future model will move away from <i>python</i> as the primary language &amp; shift to GPU<ul style="list-style-type: none"><li>Favoring GPU is driven by "<i>fields</i> in physics = <i>arrays/matrices</i> in math/programs"</li><li>Haven't decided which to employ: CUDA, Jax, webGL2, webGPU, Mojo or Bend?</li><li>Decided to try some existing packages developed by flatiron institute</li></ul></li></ul></li><li>Developed a log file system to track &amp; record the operating status for debugging<ul style="list-style-type: none"><li>to output script parameters (<i>**kwargs</i>) for rapid reproducibility of data in the future</li><li>to store data files &amp; folders, and their metadata for swift data import and reutilization</li></ul></li><li>Achieved automatic skipping of functions that return repeated values stored in memory<ul style="list-style-type: none"><li>via <i>@decorators</i>: let precomputation assess whether to execute the decorated function</li></ul></li><li>Wrap <i>matplotlib</i> into <i>plot_1d</i>(, <i>_2d</i>, <i>_3d</i>, <i>.gif</i> ...) for data visualization<ul style="list-style-type: none"><li>also sped up by customized multi-threading ...</li></ul></li></ul>	Matlab   Mathematica   JavaScript   Python
LabView Projects	BB84 QKD protocol simulation & distributed optical fiber sensing	– 2021.06
	<ul style="list-style-type: none"><li>Verified the information security of photon_polarization_state-related BB84 protocol</li><li>Visualized the distribution of anomalies along the fiber optic cable from user data</li></ul>	LabView

<sup>2</sup>Non-linear Angular Spectrum Theory (= Nonlinear Fourier Optics in Research Projects)

Hanging Assist	<p><b>AFK/Bot script for game 「Duel City」— a knock-off 「Yu-Gi-Oh」</b> – 2020.04</p> <ul style="list-style-type: none"> <li>• Automatic matching: Players (PVP), NPCs (PVE)</li> <li>• Automatic switching: Multiple accounts supported + Anti-disconnection</li> <li>• Display program stages: Real time understanding of current software state</li> <li>• Stackable record: Incrementally output history for every hang-up to the log file.ini               <ul style="list-style-type: none"> <li>→ which is also loaded as the configuration file for the next boot                   <ul style="list-style-type: none"> <li>• to restore the program state from the last exit</li> </ul> </li> </ul> </li> </ul>	EPL 
Extended 1A2B	<p><b>A Code-breaking Game 「Bulls and cows」 : Guessing 4 digits → 1-9 digits</b> – 2019.09</p> <ul style="list-style-type: none"> <li>• Hardware - MicroController (C8051F350.h) version of Original 1A2B: Guessing 4 numbers</li> <li>• Software - VC++6.0 version of Upgraded 1A2B: Guessing 1-9 numbers</li> </ul>	Keil.C   C++  
DDTank Aimbots	<p><b>An inverse solving toolkit for a projectile game similar to 「Angry Birds」</b> – 2018.04</p> <ul style="list-style-type: none"> <li>• Established an aerodynamic model with air resistance <math>R = -kv</math> for the game DDTank               <ul style="list-style-type: none"> <li>→ by solving <math>v' \propto R + F</math>, where driving force <math>F = \text{gravity } G + \text{wind force } W</math></li> <li>→ which lead to the core transcendental equation <math>1 - e^{kt} + kt = k^2 M(F; \Delta r, \hat{v}_0)</math></li> <li>→ that can be numerically solved by Newton's method for <math>t</math> with given <math>k, F; \Delta r, \hat{v}_0</math></li> <li>→ Finally, for each <math>\Delta r, \hat{v}_0</math>, one can obtain corresponding initial velocity <math>v_0(k, F; t, M)</math> <ul style="list-style-type: none"> <li>• after <math>k, F</math> are determined (by the game engine itself)</li> </ul> </li> <li>→ <math>v_0</math> ends up the very info required to accurately hit an enemy at a distance of <math>\Delta r</math> from you</li> </ul> </li> <li>• Software Features: multi-OS/end, multi-hit_mode, multi-trajectory, multi-thread supported               <ul style="list-style-type: none"> <li>→ Multi-OS: classic Web game on Windows, Mobile game on Android &amp; Android Emulator</li> <li>→ Multi-hit_mode: charge-mode for value <math>v_0</math>, drag_mode (like angry birds) for extended curve</li> <li>→ Multi-trajectory: predicts up to <math>6 = (1 + 2) \cdot 2</math> trajectories for the player: split 3 + backward 3</li> <li>→ Multi-threading: succeeded in coordinating multiple timers to implement multi-threading</li> </ul> </li> <li>• Capturing game data semi-automatically with computer vision purely               <ul style="list-style-type: none"> <li>→ call <code>dm.findmulticolorEX()</code> in <code>dm.dll</code> for pixel-level monitoring</li> </ul> </li> </ul>	VBA Excel   E4A   EPL  
Three e-books	<p><b>Freely explored math, physics, and programming with raw intellect</b> – 2017.09</p> <ul style="list-style-type: none"> <li>• Book 1: mainly on mathematics, some intriguing chapters are:               <ul style="list-style-type: none"> <li>→ Multinomial theorem: <math>(\sum_{i=1}^n a_i)^m = \sum \frac{m!}{\prod_{i=1}^n b_i!} \prod_{i=1}^n a_i^{b_i}</math> over <math>\{b_i \geq 0\}</math>, where <math>\sum_{i=1}^n b_i = m</math></li> <li>→ Strive to get the general formula for the n-th derivatives <math>f(g(x))^{(n)}</math> of a composite function</li> <li>→ Connection between the sums of certain series and the indefinite integrals of their terms</li> <li>→ Explaining Euler's formula <math>a + b - c = n</math> through topology</li> <li>→ Retracing the birth of the determinant calculation rules</li> </ul> </li> <li>• Book 2: up to 12 programs designed to solve mathematical / physical problems               <ul style="list-style-type: none"> <li>→ Multinomial theorem <math>\implies</math> Microstate count <math>\Omega_l = \frac{(g_l + a_l - 1)!}{(g_l - 1)! a_l!}</math> of Bose-Einstein systems</li> <li>→ All solutions <math>\{b_i\}</math> that meet the condition <math>\sum_{i=1}^m i \cdot b_i = m</math> of the Faà di Bruno Formula</li> <li>→ Deep recursion algorithms for partition number <math>P(n)</math> &amp; the two aforementioned contexts</li> <li>→ General solution <math>\{x_i\}</math> of multivariable linear Diophantine equation <math>\sum_{i=1}^n a_i \cdot x_i = b</math></li> <li>→ Complete solution <math>v_{\max}, v_{\min}</math> to the Double Comb/Ruler problem</li> <li>→ Minimum integer solution <math>x, y</math> of linear Diophantine equation <math>a \cdot x + b \cdot y = c</math></li> </ul> </li> <li>• Book 3: geometry-related mathematics &amp; physics               <ul style="list-style-type: none"> <li>→ Spherical trigonometry: from which I designed a non-Euler_angle rotation operator for NLAST                   <ul style="list-style-type: none"> <li>• which converts direction <math>\theta, \phi</math> of a 3D real vector <math>v</math> between two coordinate systems</li> </ul> </li> <li>→ Special relativity: Had it been animated (by Manim?), it would have looked stunning</li> </ul> </li> </ul>	C++ 

Rulesmd.ini

Modified rules.ini of 「Red Alert II」's 17 mods

- Conflict-free key-value pairs, game-easing buildings, cooldown-free teleporting minecarts
- Mental Omega v3.3.6: the modified rulesmo.ini for mo-3.3.6 has now been added

– 2016.09

\*.ini

Static Web Pages

Personal website containing decryption elements

- All of these constitutes the exploration, shouting, and wandering of that personal period
  - clues for cracking password, modifying game files (e.g. Stranded II, Star Wolves 3)
  - bi-directional links between pages, space exploration, hand-picked background music
- Explore freely until you decrypt the password and unlock the hidden webpages
  - Solve the riddle! Or you'll be stuck here: in the middle of nowhere forever!

– 2014.05

HTML

## Historical Details

Doctoral	Activities Academia	24 – 27	2022.09 – 2025.06
Postgraduate	Activities Courses Academia	22 – 24	2020.09 – 2022.06
Undergraduate	Activities Courses	18 – 22	2016.09 – 2020.06
Senior-high-school	Activities	15 – 18	2013.09 – 2016.06