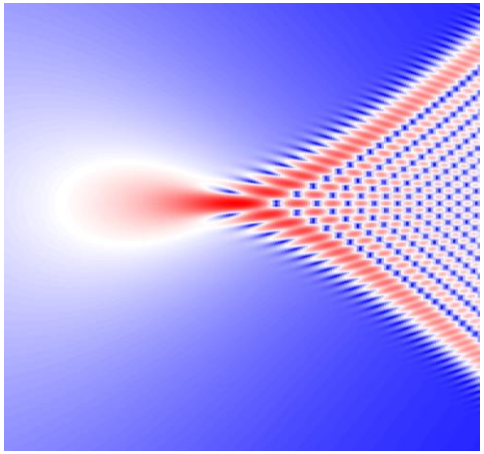
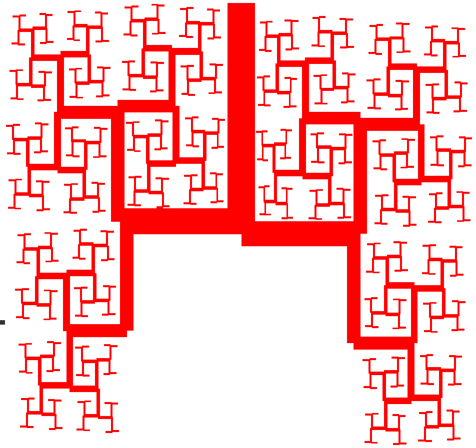


Complex and Catastrophic Phenomena in Physics and Biology



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The structure of quantum carpets in a chiral carbon nanotube

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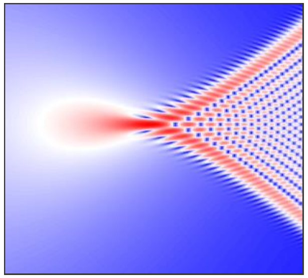
Charged & Neutral Particles Channeling Phenomena 2023
4-9 June 2023, Riccione, Italy.



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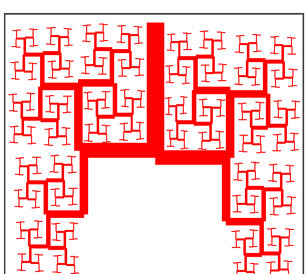

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A brief history of the morphological approach to analyzing the rainbow channeling effect.

- 2. Quantum carpets in sealed boxes:

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- 3. Quantum carpets in chiral single-wall carbon nanotubes (SWCNT)

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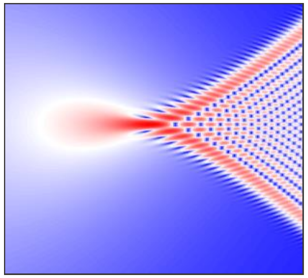
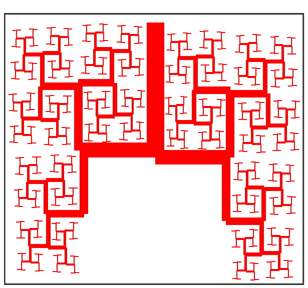
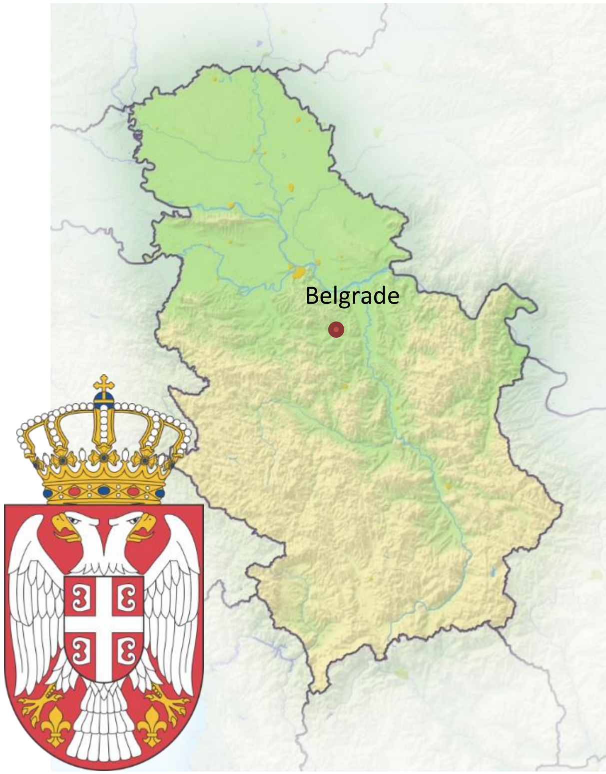
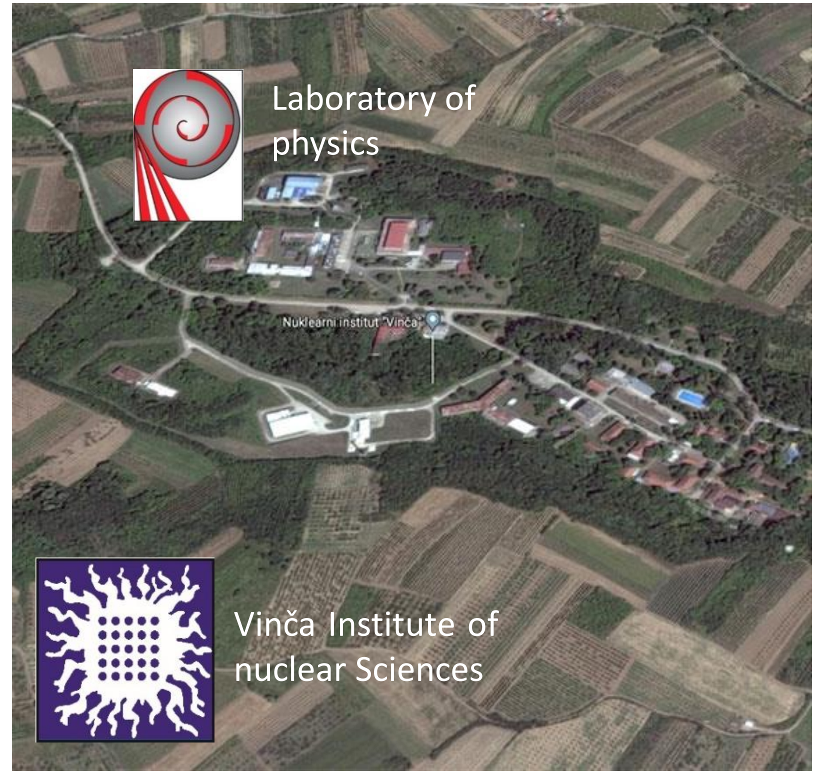




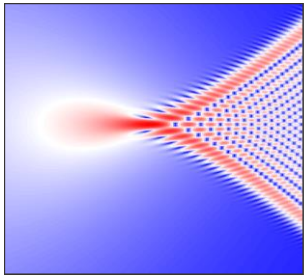
Introduction





The institute was established in 1948 by Pavle Savić, a close collaborator of Irène Joliot-Curie and Peter Kapitza. In the early years, research revolved around two reactors supplied by the USSR. Both reactors were shut down after the Chornobyl accident and the subsequent cancelation of the nuclear program in 1984.

Today the Institute is a multidisciplinary scientific research institute that carries out fundamental, developmental, and applied research in natural, technical, and technological sciences. It has many laboratories, among which the laboratory of physics is the oldest.



Introduction

The application of the topology and catastrophe theory in the investigation of materials was pioneered in 1985 by N. Nešković in his model of crystal rainbows occurring in ion transmission through planar or axial channels of crystals in the channeling mode.

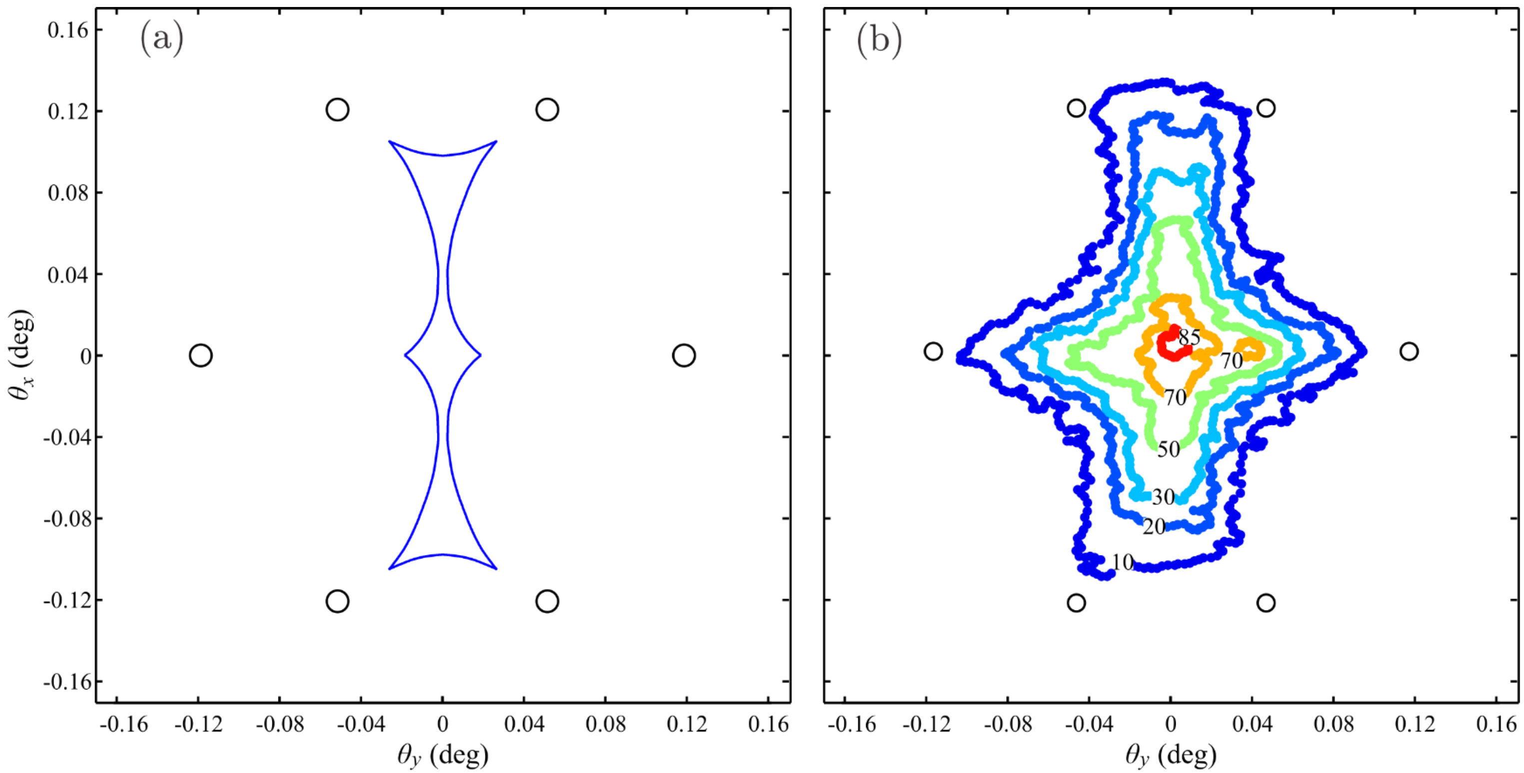
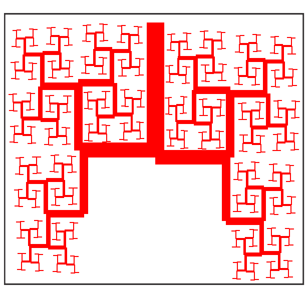
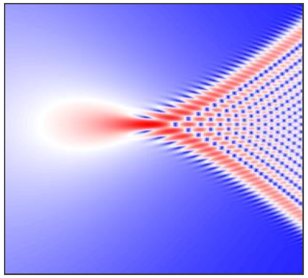


Figure 1. (a) Rainbow line in the TA plane for 7-MeV protons transmitted through <110> channel of 150-nm long Si crystal, assuming Lindhard's potential. (b) Corresponding experimental angular distribution. Open circles correspond to angular coordinates of atomic strings.





Positron channeling in SWCNT

Nanotube is a sheet of graphene rolled up to form a tube. The sequence of correlated small-angle scatterings on nanotube atoms gently steers the trajectory of a channeled positron.

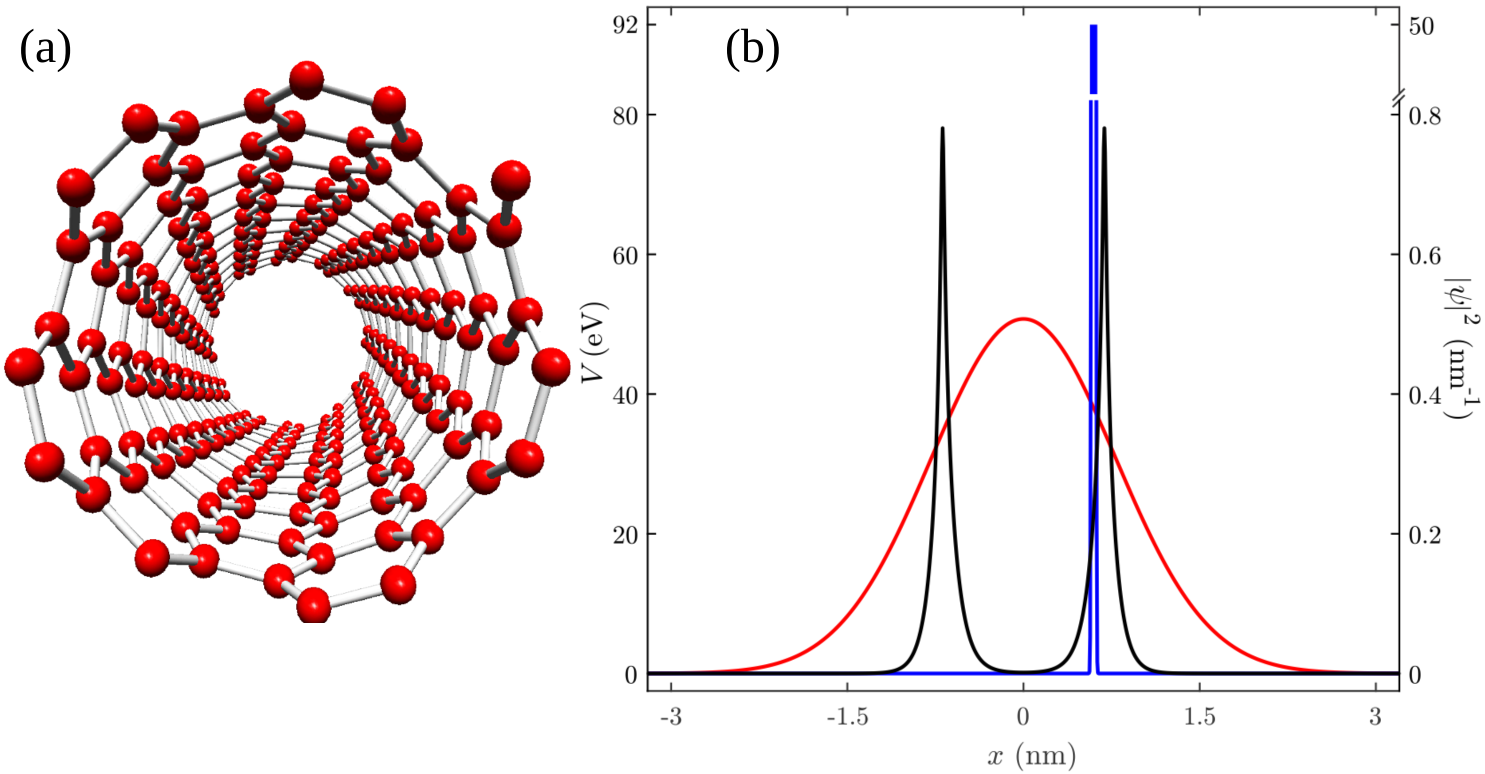
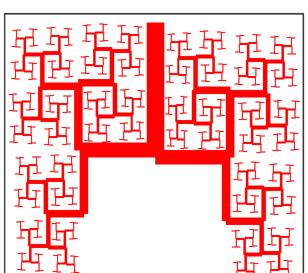
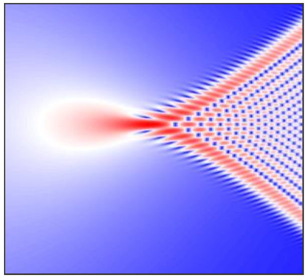


Figure 2. (a) Arrangement of carbon atoms forming a chiral nanotube. (b). The black line shows a y=0 cross-section of SWCNT's potential $V(x)$; Blue and red lines show the positron's initial probability densities used in the calculations.





Quantum carpet in a sealed box

For arbitrary ψ_o, an analytical solution of this problem has the following form:

$$\psi(x,z) = \sum_{n=1}^{\infty} c_n \varphi_n(x) \exp\left[-2\pi i \frac{zn^2}{l_r}\right], \qquad l_r = \frac{16}{\pi} k_z R^2, \qquad \varphi_n(x) = \begin{cases} \frac{1}{R} \sin\left(\frac{n\pi x}{2R}\right) & \text{for } n \text{ even} \\ \frac{1}{R} \cos\left(\frac{n\pi x}{2R}\right) & \text{for } n \text{ odd} \end{cases}$$

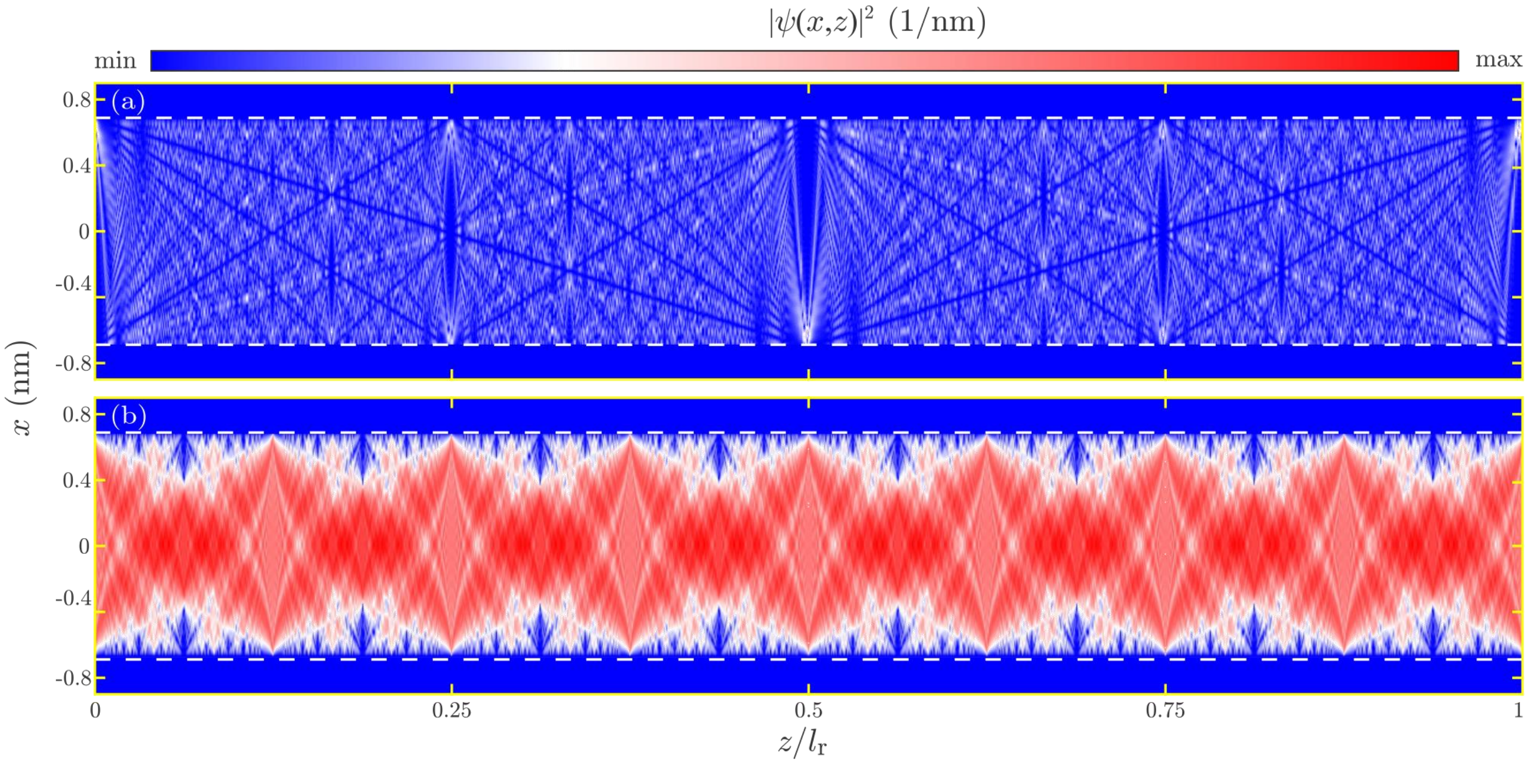
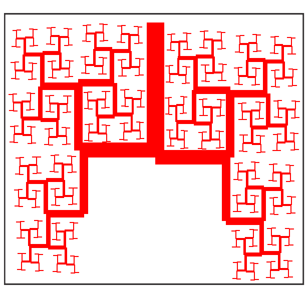
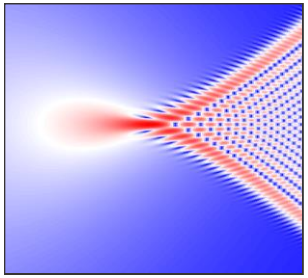


Figure 3. The corresponding evolution of the blue (a) and the red (b) initial wave packets form Fig. 2(b). White lines show nanotube walls.





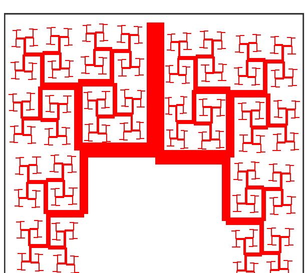
Quantum carpet in a sealed box

1. Introduction

2. Q-carpets in sealed boxes

3. Q-carpets in chiral nanotubes

4. Conclusions



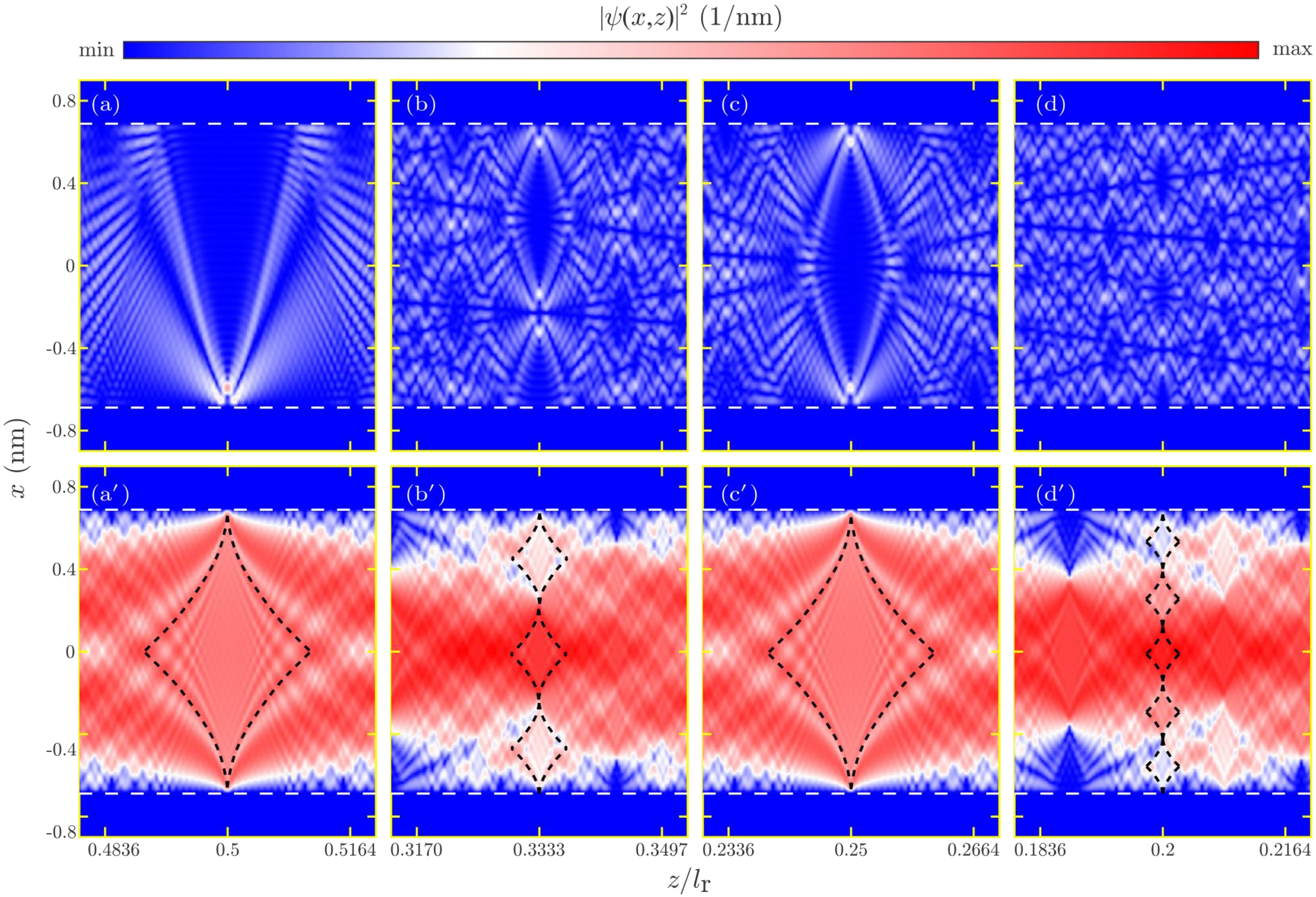
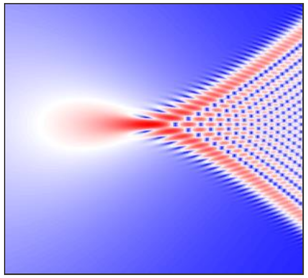


Figure 4. Enlarged views of carpets from Fig 3(a) and (b), respectively, in the vicinity of the first four fractional revivals. The white lines show nanotube walls.



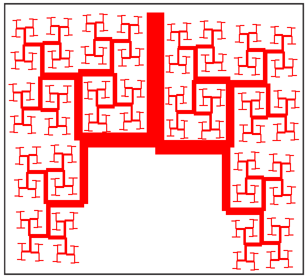
Quantum carpet in a SWCNT

1. Introduction

2. Q-carpets in sealed boxes

3. Q-carpets in chiral nanotubes

4. Conclusions



In the case of the actual nanotube potential, the quantum carpet was obtained numerically using the method of Chebyshev global propagation.

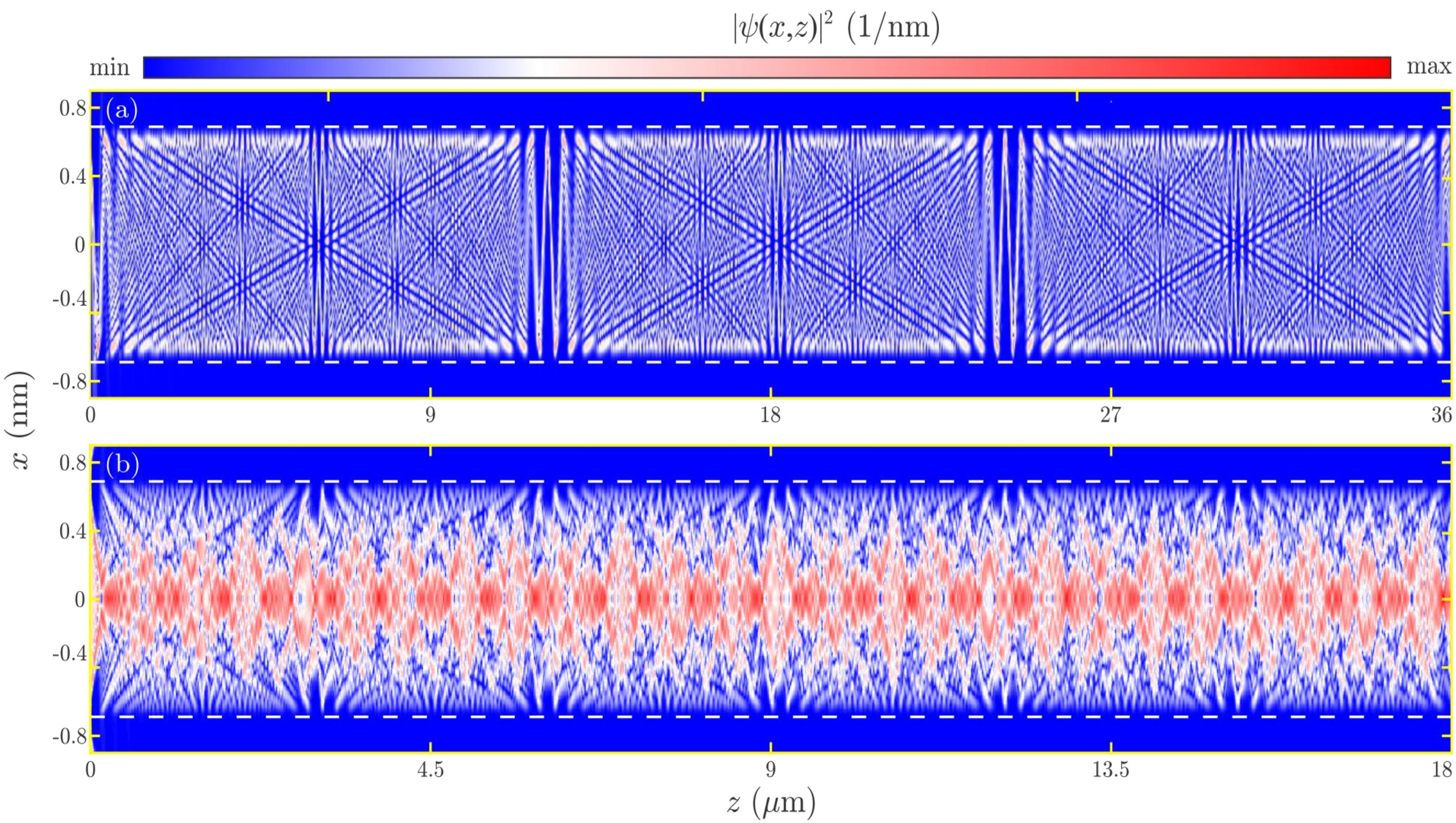
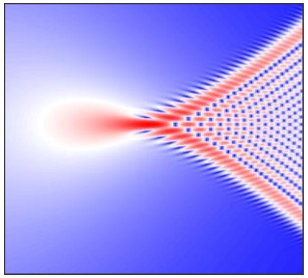


Figure 7. The corresponding evolution of the blue (a) and the red (b) initial wave packets form Fig. 2(b) in the potential of SWCNT. White lines show nanotube walls.



Quantum carpet in a SWCNT

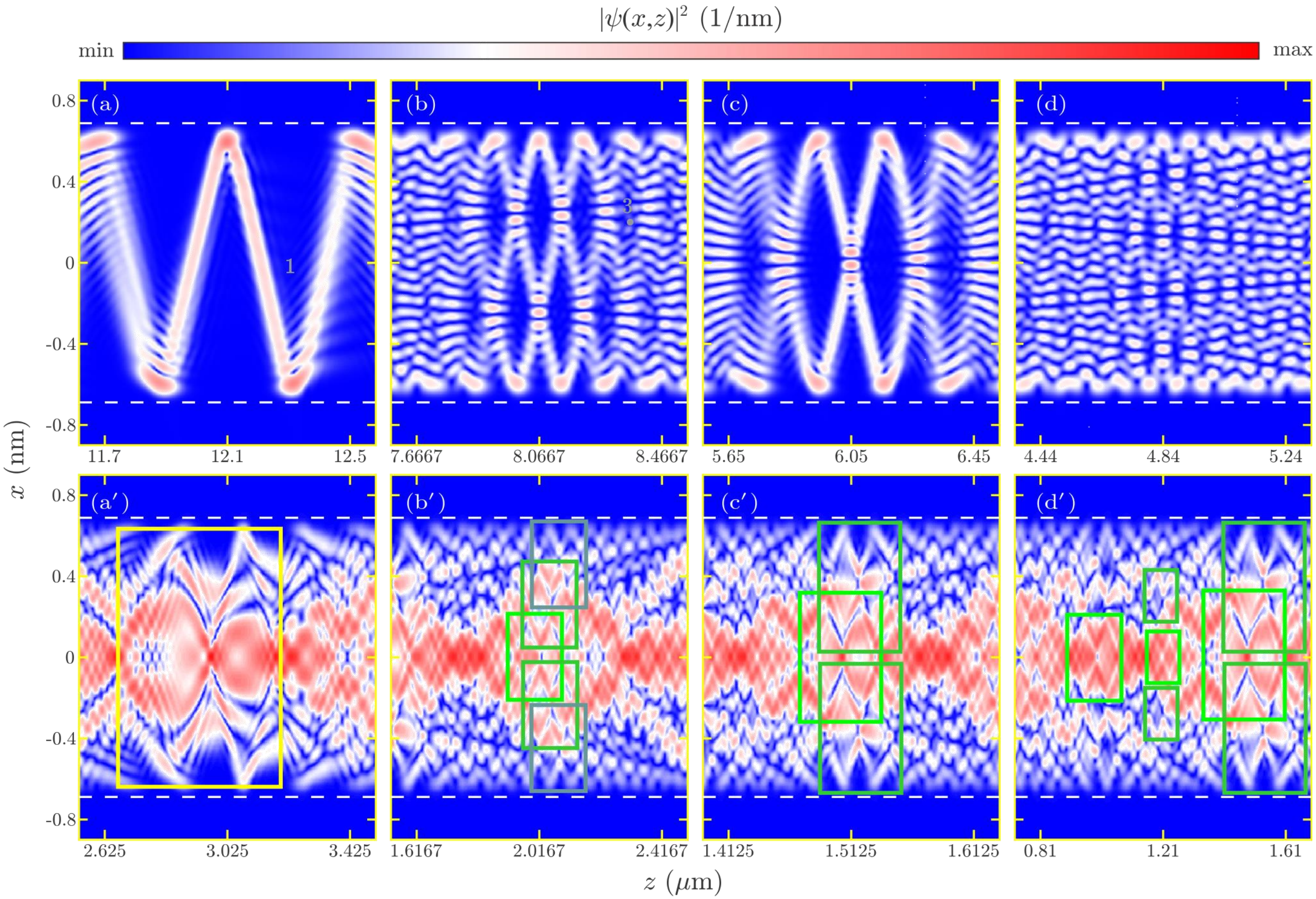
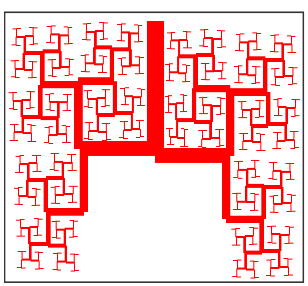
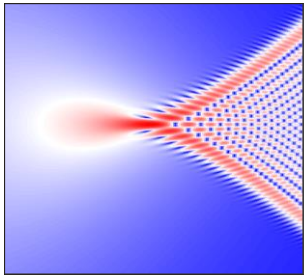


Figure 8. (a)–(d) Enlarged views of carpets from Fig. 7(a) at $z=L_r/2$, $L_r/3$, $L_r/4$, and $L_r/5$ respectively. The full black line shows the corresponding classical trajectory. (a')–(d') The corresponding enlarged views of carpets from Fig. 7(b) The white, dashed lines show the nanotube's walls.





Conclusions

- Contrary to the firmly established belief, It is shown that the superposition of continuous states can produce quantum carpets. This result suggests that it is possible to generalize the validity of Poincaré's recurrence theorem to the continuous states, with the small caveat that reoccurrences cannot occur infinitely often.

- The model also provides additional insight into the carpet's coherence-loss process and can be used to understand quantum decoherence better.

- It has been shown that the anisochronicity of the nanotube potential and the initial wave packet's width strongly influence the quantum carpet's structure. For narrow initial wave packets, the carpet is woven only by some full and fractional wave revivals. As a result, the carpet is periodic. For the wide initial wave packet, the carpet is aperiodic and irregular.

- The structure of quantum carpets in ananisochronies potentials cannot always be explained by quadratic dependence of energy eigenvalues on the principal quantum number or equivalent quadratic dependence of resonant energy on the resonance counting index.