AFRICAN SCHOOL OF FUNDAMENTAL PHYSICS AND APPLICATIONS ASP 2016

1 – 19 August 2016

Kigali, Republic of Rwanda

DECOHERENCE OF POLARON IN DELTA POTENTIAL WELL NANOSTRUCTURES

Presented

by

Florette Corinne FOBASSO MBOGNOU

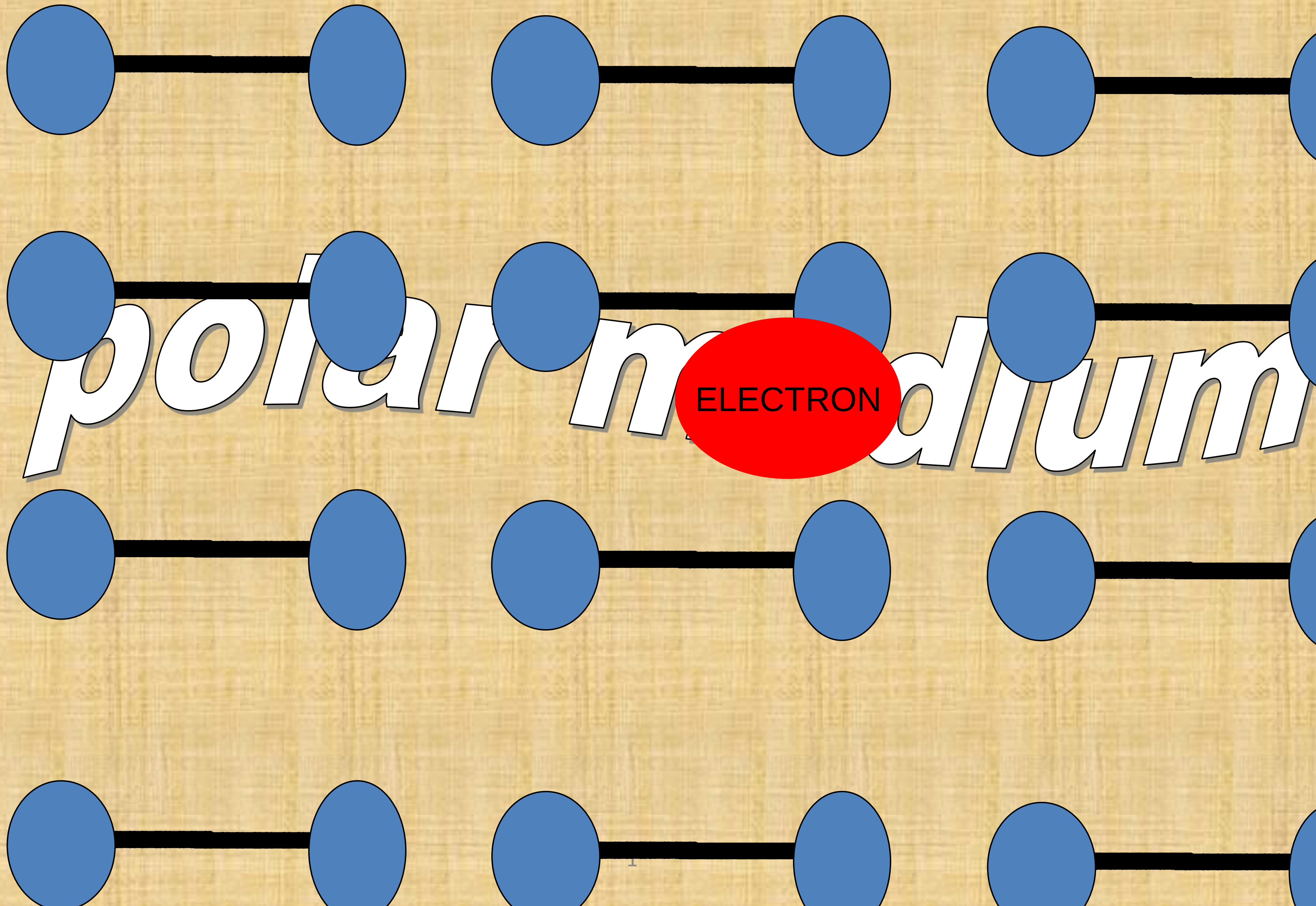
OUTLINE

- **INTRODUCTION**
- **VIEW ON POLARONS**
- **THEORETICAL MODEL**
- **CONCLUSION**

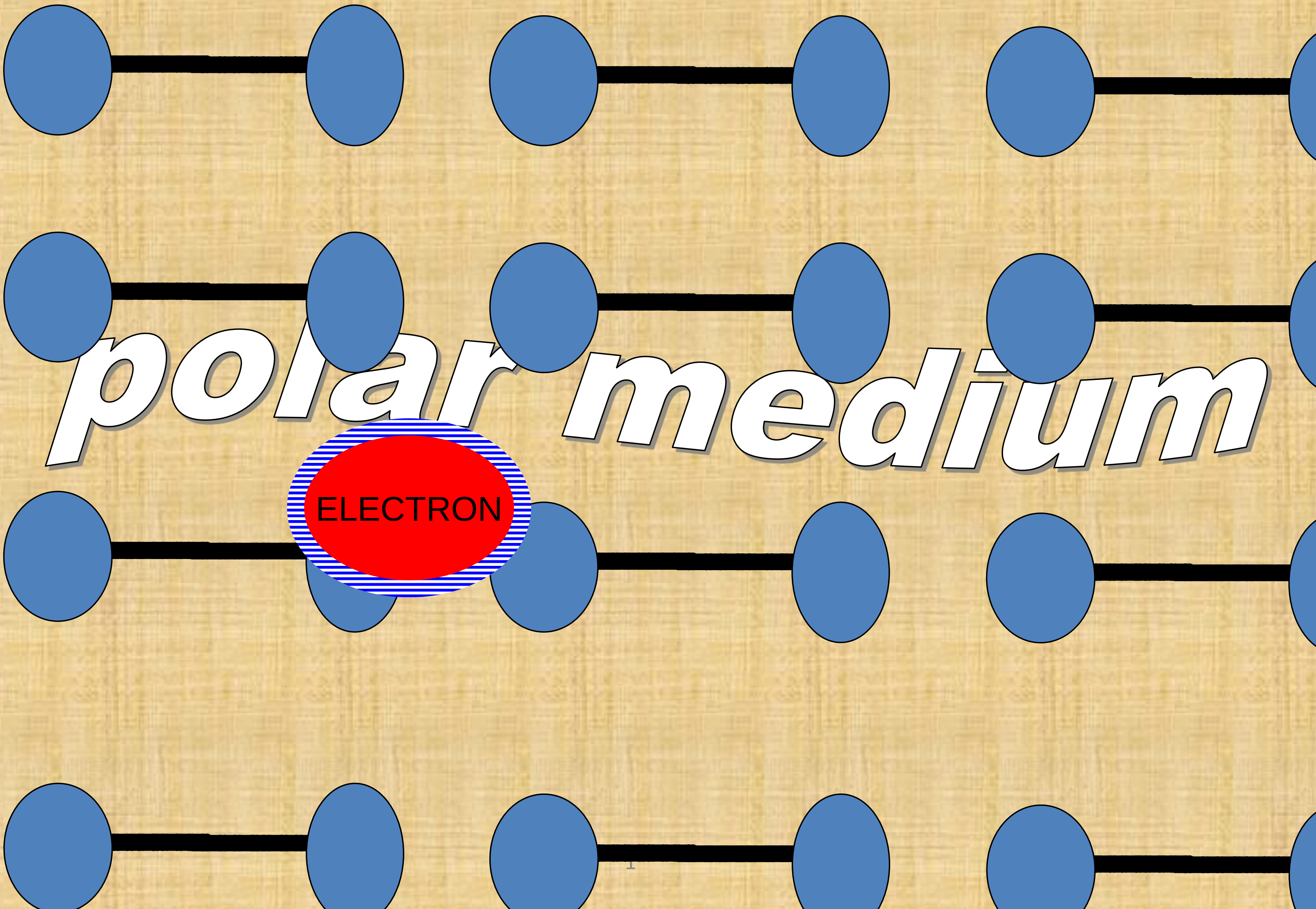
INTRODUCTION

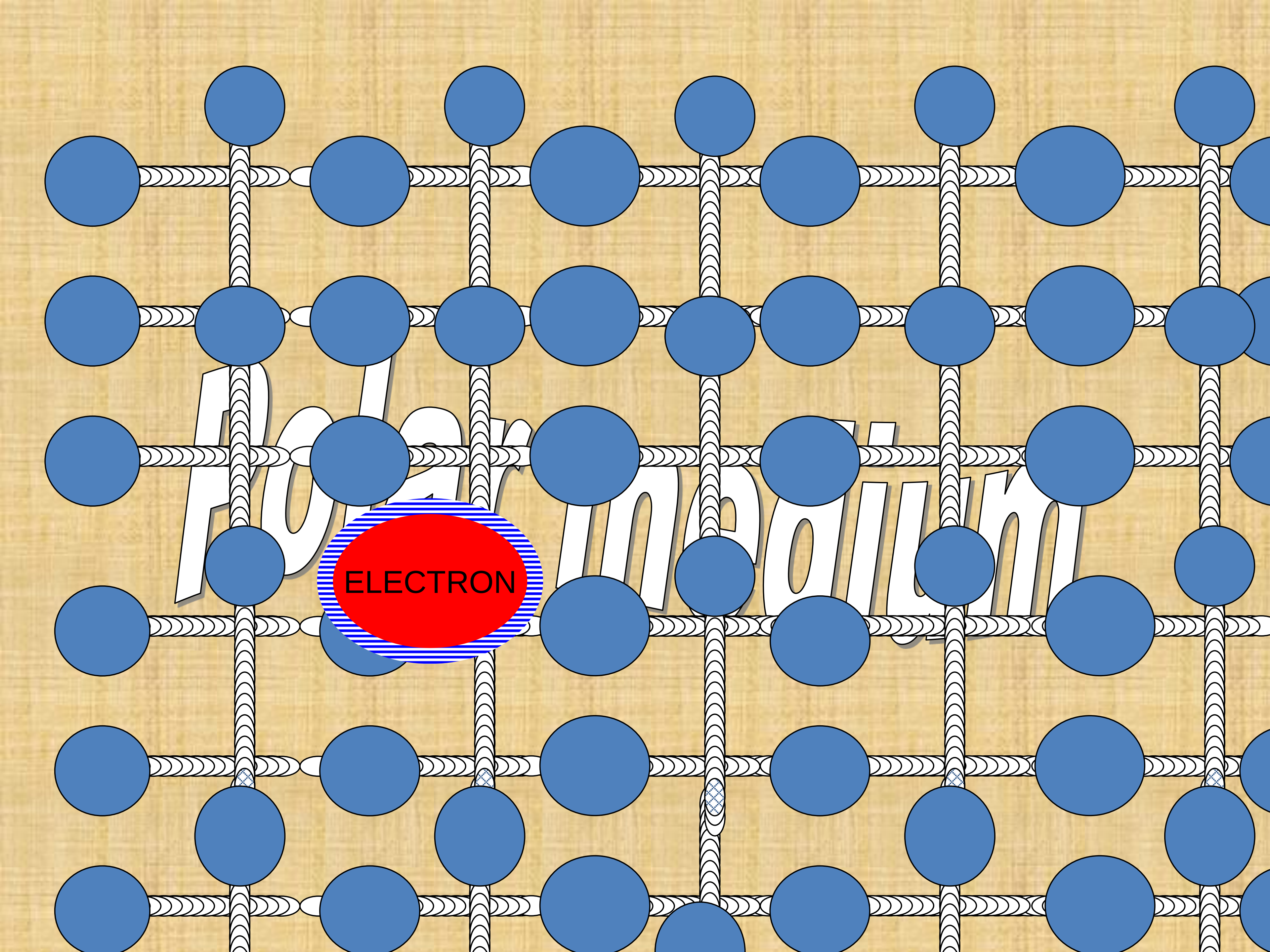
POLARON: predicted by Lev Davidovich Landau in 1933

VIEW ON POLARON


polar
ELECTRON

polar medium

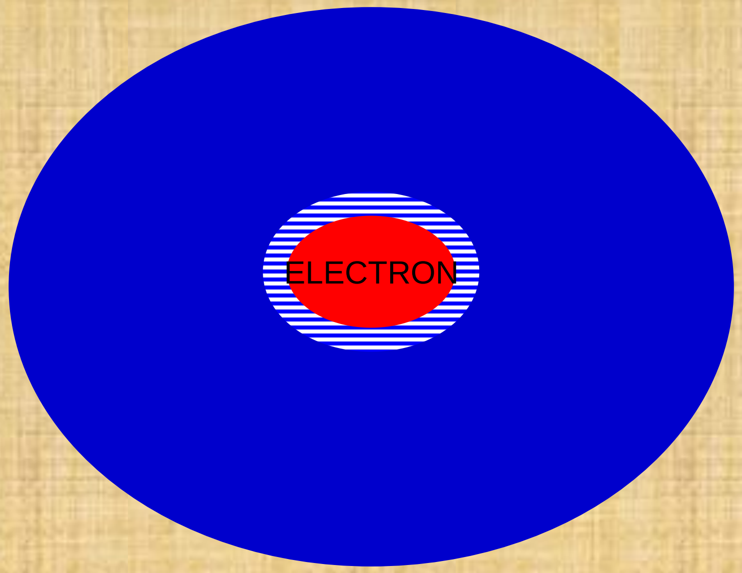



Polar medium
ELECTRON

Phonon

électron

Polarisation



POLARON

The motivation in the investigation of the polaron problem is the importance of the interaction between electrons and the crystal lattice in nanoscale and novel superconducting systems and especially in high Tc cuprates and colossal magnetoresistance (CMR) in the manganese oxides with perovskite structure.

The polaronic effects appear as a result of the strong electron-lattice interaction. In this case, a moving electron polarizes the lattice, and a shift in positions of neighbouring ions forms a potential “box” or creates a potential well, which traps the electron even in a perfect crystal lattice.

A polaron is a unit containing an electron that is moving with the lattice polarization caused by the electron itself.

THEORETICAL MODEL

ENERGY

The electron under consideration is moving in a polar crystal in a tunable barrier potential and interacting with bulk LO phonons, under the influence of an electromagnetic field along the z- direction with vector potential

$$A = B\left(-y/2, x/2, 0\right)$$

The Hamiltonian of the electron-phonon interaction system can be written as:

$$H = \frac{1}{2m}\left(-\hbar^2\nabla^2\right) + \frac{1}{8}m\omega_c^2\left(x^2 + y^2\right) - e^*Fz + \sum_{\vec{q}}\hbar\omega_{LO}a_{\vec{q}}^{+}a_{\vec{q}} + \sum_{\vec{q}}\left[V_{\vec{q}}a_{\vec{q}}\exp\left(i\vec{q}.\vec{r}\right) + h.c\right] - \frac{\kappa}{a}\delta\left(x\right) \quad (1)$$

$\omega_c = \dfrac{e\mathbf{B}}{mc}$ is the Cyclotron frequency

ENERGY

Following the Pekar Type variational method

$$|\psi_0\rangle = \left(\frac{\lambda}{\pi}\right)^{1/2}\left(\frac{\mu}{\pi}\right)^{1/4}\exp\left(-\lambda x^2/2\right)\exp\left(-\lambda y^2/2\right)\exp\left(-\mu z^2/2\right)|O_{ph}\rangle \qquad (2)$$

$$E_0 = \langle\psi_0|H'|\psi_0\rangle \qquad (*)$$

$$|\psi_1\rangle = \left(\frac{\lambda_1^2}{\pi}\right)^{1/2}\left(\frac{\mu_1}{\pi}\right)^{1/4}\exp\left(-\lambda_1 x^2/2\right)\exp\left(-\lambda_1 y^2/2\right)\exp\left(-\mu_1 z^2/2\right)\rho\exp\left(\pm i\phi\right)|O_{ph}\rangle \qquad (3)$$

$$E_1 = \langle\psi_1|H'|\psi_1\rangle \qquad (2*)$$

λ, μ, λ_1, μ_1 are variational parameters

ENERGY

We can have the different GFES energies of each potentials:

$$E_0 = \lambda + \frac{\mu}{2} + \frac{\kappa}{a}\sqrt{\frac{\lambda}{\pi}} + \frac{\omega_c^2}{16}\frac{1}{\lambda} - \frac{e^* F}{\sqrt{\pi\mu}} - 2\alpha\xi \qquad (4)$$

$$\xi = \left(\frac{2\lambda}{\pi\left(1-\frac{\lambda}{\mu}\right)}\right)^{1/2} \arcsin\left(1-\frac{\lambda}{\mu}\right)^{1/2} \qquad (3*)$$

$$E_1 = \frac{\lambda_1}{2} + \frac{\mu_1}{2} + \frac{\kappa}{a}\sqrt{\frac{\lambda}{\pi}} + \frac{\omega_c^2}{8}\frac{1}{\lambda_1} - \frac{e^* F \lambda_1}{\sqrt{\pi\mu_1}} - 8\alpha\xi_1 \qquad (5)$$

$$\xi_1 = \left(\frac{2\lambda_1}{\pi\left(1-\frac{\lambda_1}{\mu_1}\right)}\right)^{1/2} \arcsin\left(1-\frac{\lambda_1}{\mu_1}\right)^{1/2} \qquad (4*)$$

Decoherence Time and Entropy

Based on the Fermi Golden Rule, the spontaneous emission rate can be written in the following form:

$$\tau^{-1} = \frac{e^2 (\Delta E)^3 \left|\langle 0|r|1\rangle\right|^2}{2\pi c \varepsilon_0 \hbar^2 \eta} \tag{6}$$

where c is the speed of light in vacuum, ε_0 is the vacuum dielectric constant, η is the coeffcient dispersion, ΔE is the energy level spacing between $|0\rangle$ and $|1\rangle$, τ is decoherence time.

The Shannon Entropy is given as follow

$$S = -K \int P \log P \tag{7}$$

With $P = Q(r,t)$

NUMERICAL RESULTS

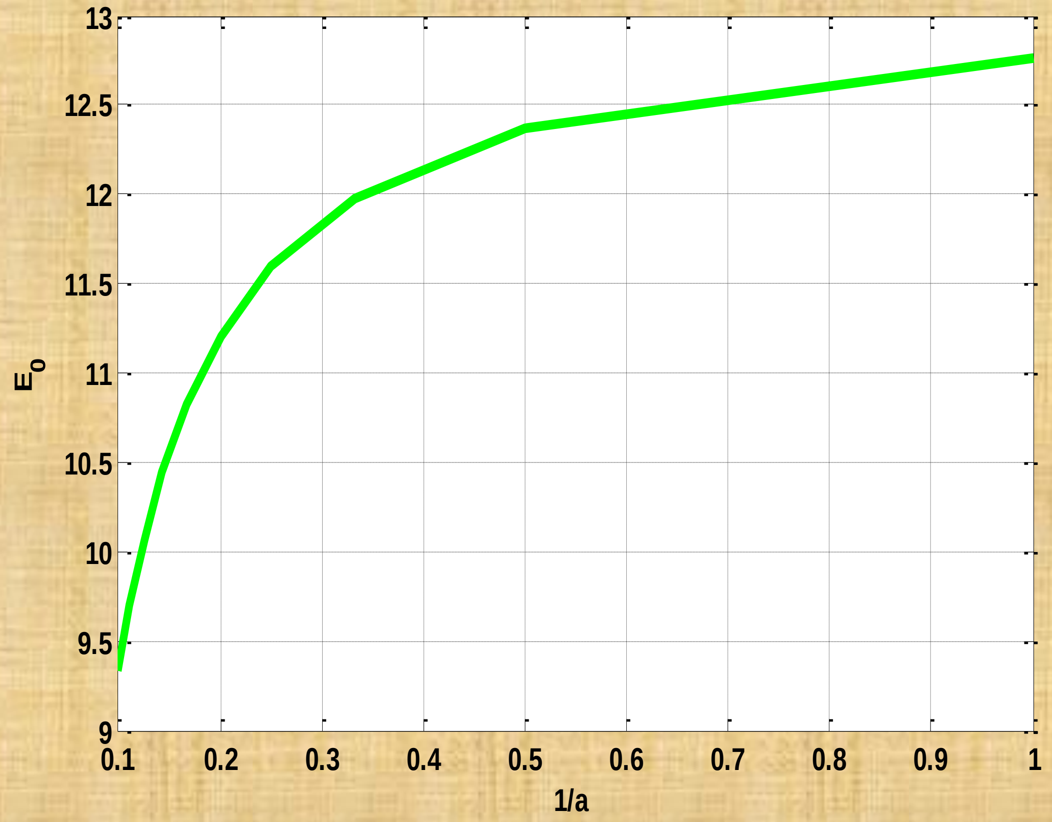


Figure 1: Ground state energy for a delta potential as function of the reciprocal of the confinement length a.

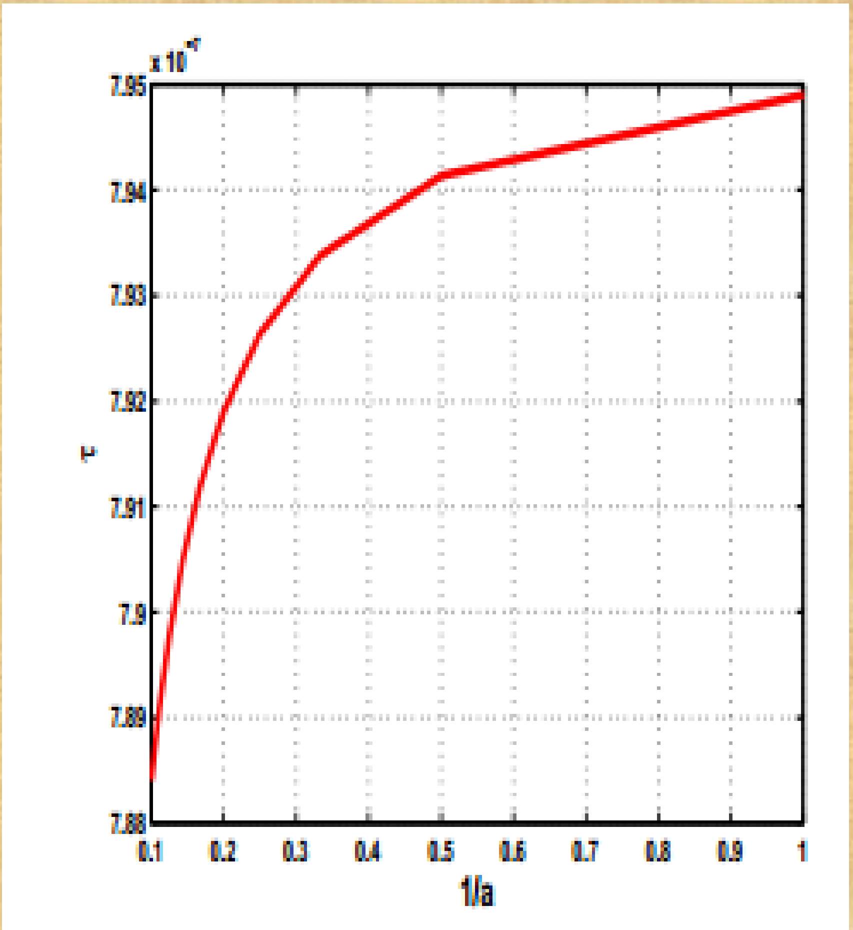


Figure 2: Polaron decoherence time for delta potential as a function of the reciprocal of the confinement length a.

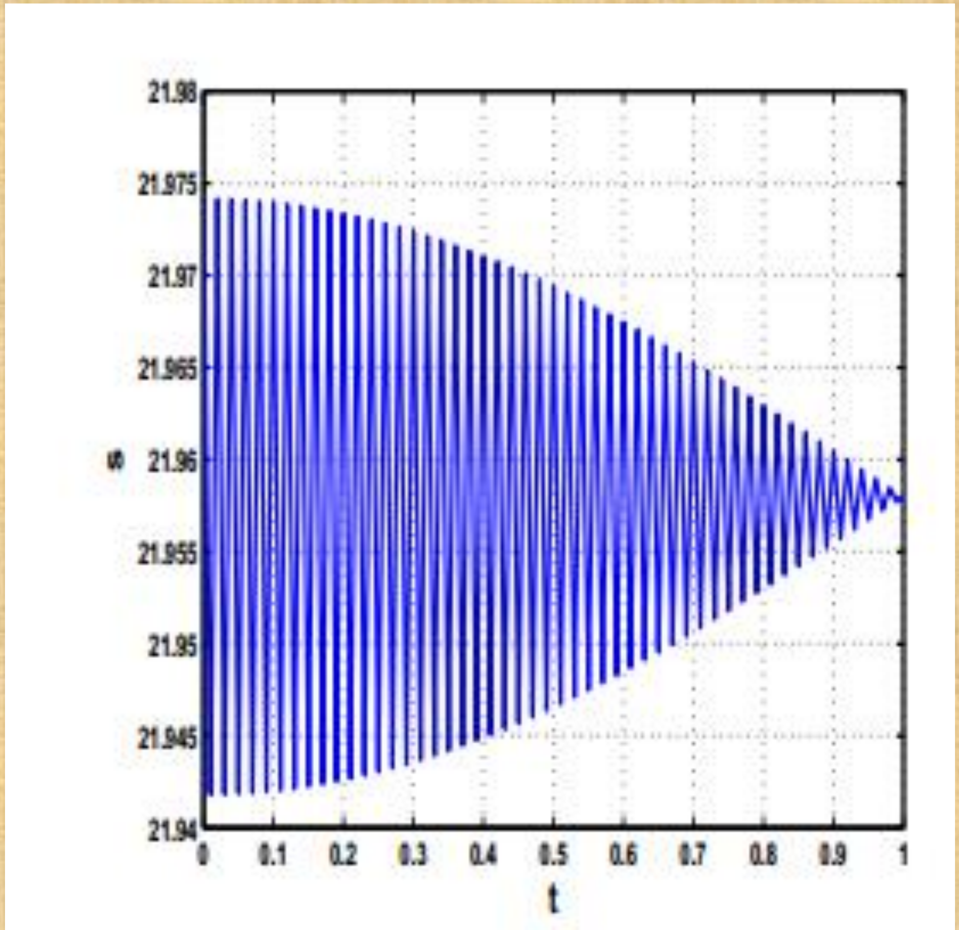


Figure 3: Time evolution of entropy of: a delta potential.

A. J. Fotue, M. F. C. Fobasso et al., Eur. Phys. J. Plus, Vol. 131, No. 205 (2016).

V- CONCLUSION

- It is found that the ground state energies are increasing functions of the reciprocal of the confinement length.

- The decoherence time increases with increasing reciprocal of the confinement.

- The Shannon entropy shows that the system tend to be coherent in a certain period of time.

PERPESTIVES

- Feynman variational method so that the results obtained by the two methods can be compared
- Study the temperature effect
- Study the life time of polaron
- Take into account the screening effect in this polaronic system
- We entend to better linked theory and practice by using real semiconductors with real parameter used to design electronic devices.

THANK YOU FOR YOUR KIND ATTENTION