Mesoscopic Physics in Complex Media, 03003 (2010)
DOI:10.1051/iesc/2010mpcm03003

Light emission, local density of states and C_0 speckle correlation in strongly scattering media

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Article published online by EDP Sciences and available at http://www.iesc-proceedings.org or http://dx.doi.org/10.1051/iesc/2010mpcm03003

Light emission, local density of states and C_0 speckle correlation in strongly scattering media

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Summer school "Mesoscopic Physics in Complex Media"

1 Introduction

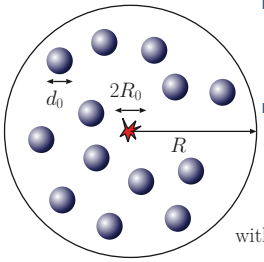
Computation of the **imaginary part of the Green function** at the position of the source in a random medium related to

- the **spontaneous decay rate** of the emitter;
- the **Local Density Of States** (LDOS);
- the C_0 **intensity correlation**.

A study related to fundamental questions in mesoscopic physics as the ability

- to **image** local optical properties deep inside in the system;
- to **control** light emission by multiple scattering.

2 Physical and numerical model [1, 2]



- Scatterers: N dipoles of polarisability

$$\alpha(\omega) = \frac{-3\pi c^3 \gamma}{\omega^3(\omega - \omega_0 + i\gamma/2)}$$

- Emitters: 1 source of decay rate ($\propto$ LDOS)

$$\boxed{\frac{\Gamma}{\Gamma_0} = \frac{\rho}{\rho_0} = 1 + \frac{6\pi}{k}\Im\left[\mathrm{Tr}\,\overleftrightarrow{\mathbf{S}}(\mathbf{r}_0, \mathbf{r}_0, \omega)\right]}$$

with $\overleftrightarrow{\mathbf{S}}(\mathbf{r}_0, \mathbf{r}_0, \omega) = \alpha(\omega) k^2 \sum_{k=1}^{N} \overleftrightarrow{\mathbf{G}}_0(\mathbf{r}_0, \mathbf{r}_k) \overleftrightarrow{\mathbf{G}}_k$,

and $\overleftrightarrow{\mathbf{G}}_j = \overleftrightarrow{\mathbf{G}}_0(\mathbf{r}_j, \mathbf{r}_0) + \alpha(\omega) k^2 \sum_{k=1, k\neq j}^{N} \overleftrightarrow{\mathbf{G}}_0(\mathbf{r}_j, \mathbf{r}_k) \overleftrightarrow{\mathbf{G}}_k$.

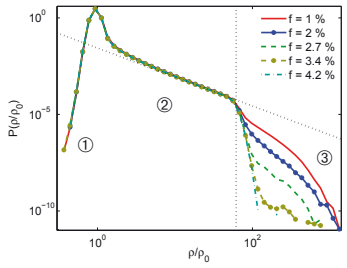
4 LDOS and C_0 speckle correlation [3]

- LDOS fluctuations and C_0 speckle correlation are equal [4]:
  C_0 is of infinite range and a non-universal intensity correlation function [5]:

$$\boxed{C_0 = \frac{\langle \rho^2(\mathbf{r}_0, \omega)\rangle}{\langle \rho(\mathbf{r}_0, \omega)\rangle^2} - 1 = \frac{\mathrm{Var}\left[\rho(\mathbf{r}_0, \omega)\right]}{\langle \rho(\mathbf{r}_0, \omega)\rangle^2}}$$

Expression valid for **all transport regime** for a non-absorbing medium.

- LDOS distribution $P(\Gamma)$:



① $\Gamma < \Gamma_0$: collective interaction (multiple scattering)

② $P(\Gamma) \propto \Gamma^{-3/2}$: Near-field interaction with one scatterer

③ Near-field interaction with more than one scatterer sensitive to the correlation parameter f

$N = 100$, $\omega = \omega_0 + \gamma$, $\omega_0 = 3 \times 10^{15}$ Hz, $\gamma = 1 \times 10^9$ Hz, $R = 1.2\,\mu$m, $R_0 = 0.05\,\mu$m, $k\ell_B = 19$, $f = N(d_0/2)^3/(R^3 - R_0^3)$

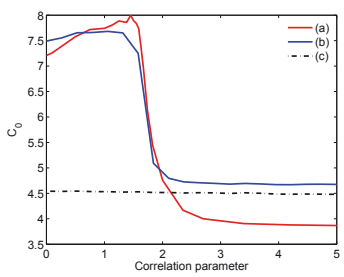
- Influence of regime ③ on C_0:

(a) Full calculation

(b) Two nearest neighbours taken into account

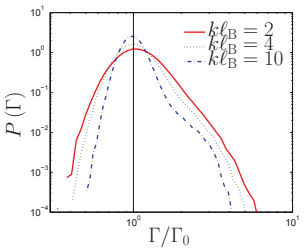
(c) Only the nearest neighbour taken into account

C_0 is strongly influenced by the correlations of the disorder.

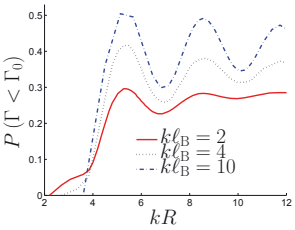


3 LDOS and multiple scattering [6]

- LDOS distribution $P(\Gamma)$ and probability $P(\Gamma < \Gamma_0)$:



Possibility of $\Gamma < \Gamma_0$ due to collective interactions (interferences)

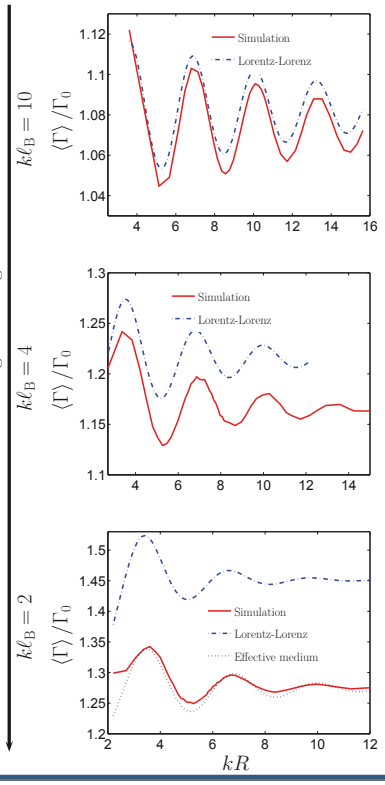


$P(\Gamma < \Gamma_0)$ can reach 50 % depending on parameters

$N = 500$, $\omega = \omega_0 \Rightarrow \lambda = 1.88\,\mu$m, $R_0 = 0.36\,\mu$m, $d_0 = 0.12\,\mu$m, $f \leq 2\,\%$

- Average LDOS $\langle\Gamma\rangle$:

Weak to strong scattering



– No correlation in position

– No recurrent scattering

– Data described with

$$\epsilon_{LL} = 1 + \frac{\rho\alpha}{1 - \rho\alpha/3}$$

– Deviation from the independant scattering approximation

– No correlation in position

– **Signature of recurrent scattering**

– Data fitted numerically with

$$\epsilon_{\mathrm{eff}} \neq \epsilon_{LL}$$

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