NON-STATISTICAL $\gamma$ RAYS FROM FRAGMENTS

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1 Introduction

Observation of the shake effects brought about by the neck rupture in fission is of great interest. From mathematical viewpoint, the rupture means break-down of the analyticity of the Hamiltonian with respect to time. Thus, muon shake in muon-induced prompt fission manifests itself in muonic conversion. The calculated probability agrees with the experiment [1, 2]. Herein we calculate the probability of emission of $\gamma$ quanta, the results are also of interest in connection with experiments [3, 4], in which works non-statistical $\gamma$ rays from $^{252}$Cf spontaneous fission are under investigation.

The process of snapping-back of the nuclear surface gives rise to the oscillations of the surface, whose lifetime is determined by the dissipation. It can be evaluated as $\tau_{\text{diss}} \approx 10^{-19}$ s [5]. The oscillations generate nonstationary electromagnetic field in space. That causes electromagnetic processes of internal conversion and $\gamma$ radiation.

The nuclear vibrations can be considered like the motion of a classical droplet. Write down the conventional expansion of the nuclear form in spherical harmonics

$$R(\theta, \phi) = R_0 \left( 1 + \beta_0 + \sum_{\lambda, \mu} \beta_{\lambda, \mu} Y_{\lambda, \mu}(\theta, \phi) \right).$$  \hfill (1)

Main properties of the fragments can be described by allowing for the quadrupole and octupole terms. Such superposition leads to a pear-like form of the nucleus. It is essential that the electric dipole term in this case must be included in eq. (1) to keep the centre of mass fixed [6], the relation $\beta_1 = -0.743\beta_2\beta_3$ following from the latter condition [1, 7]. The other consequence is the appearance of the polarization electric dipole moment in the nucleus [6]:

$$d \equiv D/e = -\kappa\beta_2\beta_3.$$  \hfill (2)

Polarizability $\lambda$ (or $\kappa$) in eq. (2) can be evaluated e.g. from formulae [6, 7], which agree with experiment (see also other refs. in [7]).

Considering the oscillations quasiclassically and taking into account the relaxation, put down

$$\beta_i(t) = \beta_i^{(0)} \sin \omega_i t \exp(-\gamma_i t/2), \quad i = 2, 3.$$  \hfill (3)
Then the spectral density of the radiated energy is given in the classical limit \[8\] by the following expression:

\[
d\mathcal{E}_\omega = \frac{4}{3} |\tilde{D}_\omega|^2 ,
\]

(4)

where \(D_\omega\) is the Fourier transform of the second derivative of \(D(t)\) with respect to time. Using (2) and (3) in eq. (4), we find

\[
\tilde{D}_\omega = -\kappa \beta_2^{(0)} \beta_3^{(0)} \int_0^\infty \exp(i\omega t) \frac{d^2}{dt^2} \sin \omega_2 t \sin \omega_3 t \exp(-\gamma t/2) = \]

\[
i D_0 \frac{(\omega_2 + \omega_3)^2}{\omega - \omega_2 - \omega_3 + i\frac{\gamma}{2}} ,
\]

(5)

where \(\gamma = \gamma_2 + \gamma_3\) is the total quenching, and \(D_0 = -\kappa \beta_2^{(0)} \beta_3^{(0)}\).

Supposing \(\beta_2^{(0)} \approx \beta_3^{(0)} \approx 0.7\) \[5\], we calculate by means of formulae [7] \(d_0 \approx 5\) Fm. Using then the LDM values for a representative heavy fragment \(^{140}\text{Xe}\), which are \(\hbar \omega_2 = 2.2\) MeV, \(\hbar \omega_3 = 2.8\) MeV, and evaluating \(\gamma\) from the lifetime \(\tau_{\text{diss}} = \gamma^{-1} = 10^{-19}\) s, as it is stated previously, one immediately finds by means of eq. (4)

\[
N_\gamma = \int_0^\infty \frac{d\mathcal{E}_\omega}{\hbar \omega} \approx 8 \cdot 10^{-3} \text{ fission}^{-1} .
\]

(6)

We conclude that this value is in qualitative agreement with experiment \[3, 4\], taking into account the uncertainties connected with the value of \(\tau_{\text{diss}}\). For the value supposed, \(\tau_{\text{diss}} \approx 10^{-19}\) s, the contribution of the proposed mechanism is enough to explain the experimental value.

On the other hand, we see that this contribution is proportional to \(\tau_{\text{diss}}\). Therefore, study of non-statistical \(\gamma\) rays from fission gives direct information about dissipation in largo-amplitude collective motion represented by postrupture oscillations in the fragments.

**References**

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