Instituut voor
Kern- en Stralingsfysica
Departement Natuurkunde
Faculteit Wetenschappen

KATHOLIEKE UNIVERSITEIT
LEUVEN

NEW TECHNIQUES BASED ON THE COHERENCE WITH GAMMA-RADIATION

Promotoren:

Prof. Dr. R. Coussement
Prof. Dr. J. Odeurs

Proefschrift ingediend tot
het behalen van de graad van
doctor in de wetenschappen
door

Caroline L'abbé

2000

De auteur is Aspirant van het Fonds voor Wetenschappelijk Onderzoek - Vlaanderen.

To my father

Contents

PART II: NUCLEAR EMISSION HOLOGRAPHY

Preface

Coherence plays an important role in the interaction of γ-radiation with nuclei. The basic concept is that a single photon, when it interacts with an ensemble of nuclei, can follow several quantum mechanical paths.

Two kinds of coherence can be distinguished. First of all, there is spatial coherence between different nuclei in the sample. When a photon of right energy falls onto an ensemble of identical nuclei, it can be resonantly scattered by each one of these nuclei. According to quantum mechanics, it is impossible to distinguish between different scattering paths and to determine on which particular nucleus the scattering actually happened. The excitation, created by absorption of a single photon, is in fact spread out over the whole ensemble. One could say that all nuclei are partly excited. This delocalized, intermediate state is called a nuclear exciton. It is a coherent superposition of states in which one nucleus is excited and all the others are in the ground state. When the nuclear exciton decays, the waves emitted by all nuclei will interfere. In forward and Bragg direction the interference is constructive and the radiative intensity is enhanced compared to that of a single nucleus.
There is also energy coherence which can happen inside a single nucleus or between different nuclei. When the incident γ-quantum has a broad energy spectrum, it can excite several nuclear transitions simultaneously. Again, there are different quantum mechanical paths that can interfere.

In this thesis two new techniques are worked out which are both based on the coherence with γ-radiation.
In a first part, time-integrated synchrotron-radiation spectroscopy is developed. It is a new hyperfine interaction technique which relies on both the spatial and energy coherence.
In a second part, nuclear emission holography is treated. This technique, which allows three-dimensional imaging of nuclei, is based on the spatial coherence of radiation emitted by nuclei inside the sample.