Sudan University of Science and Technology
College of Graduate Studies

Computational Simulation of Laser Cooling and Trapping of Radium Atoms.

محاكاة حاسوبية لتبريد وإصطياد ذرات الراديوم بالليزر

A thesis Submitted for Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Laser and its Applications in Physics

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الآيــة الكريمـة

ﭧﭨﭩﭪﭫﭬﭭﭮﭯﭰﭱﭲﭳﭴﭵﭶﭷﭸﭹﭺﭻﭼﭽﭾﭿﮀﮁﮂﮃﮄﮅﮆﮇﮈﮉﮊﮋﮌﮍﮎﮏﮐﮑﮒﮓﮔﮕﮖﮗﮘﮙﮚﮛﮜﮝﮞﮟﮠﮡﮢﮣﮤﮥﮦﮧﮨﮩﮪﮫﮬﮭﮮﮯﮰﮱﯓﯔﯕﯖﯗﯘﯙﯚﯛﯜﯝﯞﯟﯠﯡﯢﯣﯤﯥﯦﯧﯨﯩﯪﯫﯬﯭﯮﯯﯰﯱﯲﯳﯴﯵﯶﯷﯸﯹﯺﯻﯼﯽﯾﯿﰀﰁﰂﰃﰄﰅﰆﰇﰈﰉﰊﰋﰌﰍﰎﰏﰐﰑﰒﰓﰔﰕﰖﰗﰘﰙﰚﰛﰜﰝﰞﰟﰠﰡﰢﰣﰤﰥﰦﰧﰨﰩﰪﰫﰬﰭﰮﰯﰰﰱﰲﰳﰴﰵﰶﰷﰸﰹﰺﰻﰼﰽﰾﰿﱀﱁﱂﱃﱄﱅﱆﱇﱈﱉﱊﱋﱌﱍﱎﱏﱐﱑﱒﱓﱔﱕﱖﱗﱘﱙﱚﱛﱜﱝﱞﱟﱠﱡﱢﱣﱤﱥﱦﱧﱨﱩﱪﱫﱬﱭﱮﱯﱰﱱﱲﱳﱴﱵﱶﱷﱸﱹﱺﱻﱼﱽﱾﱿﲀﲁﲂﲃﲄﲅﲆﲇﲈﲉﲊﲋﲌﲍﲎﲏﲐﲑﲒﲓﲔﲕﲖﲗﲘﲙﲚﲛﲜﲝﲞﲟﲠﲡﲢﲣﲤﲥﲦﲧﲨﲩﲪﲫﲬﲭﲮﲯﲰﲱﲲﲳﲴﲵﲶﲷﲸﲹﲺﲻﲼﲽﲾﲿﳀﳁﳂﳃﳄﳅﳆﳇﳈﳉﳊﳋﳌﳍﳎﳏﳐﳑﳒﳓﳔﳕﳖﳗﳘﳙﳚﳛﳜﳝﳞﳟﳠﳡﳢﳣﳤﳥﳦﳧﳨﳩﳪﳫﳬﳭﳮﳯﳰﳱﳲﳳﳴﳵﳶﳷﳸﳹﳺﳻﳼﳽﳾﳿﴀﴁﴂﴃﴄﴅﴆﴇﴈﴉﴊﴋﴌﴍﴎﴏﴐﴑﴒﴓﴔﴕﴖﴗﴘﴙﴚﴛﴜﴝﴞﴟﴠﴡﴢﴣﴤﴥﴦﴧﴨﴩﴪﴫﴬﴭﴮﴯﴰﴱﴲﴳﴴﴵﴶﴷﴸﴹﴺﴻﴼﴽ﴾﴿﵀﵁ﵐﵑﵒﵓﵔﵕﵖﵗﵘﵙﵚﵛﵜﵝﵞﵟﵠﵡﵢﵣﵤﵥﵦﵧﵨﵩﵪﵫﵬﵭﵮﵯﵰﵱﵲﵳﵴﵵﵶﵷﵸﵹﵺﵻﵼﵽﵾﵿﶀﶁﶂﶃﶄﶅﶆﶇﶈﶉﶊﶋﶌﶍﶎﶏ﶐﶑ﶒﶓﶔﶕﶖﶗﶘﶙﶚﶛﶜﶝﶞﶟﶠﶡﶢﶣﶤﶥﶦﶧﶨﶩﶪﶫﶬﶭﶮﶯﶰﶱﶲﶳﶴﶵﶶﶷﶸﶹﶺﶻﶼﶽﶾﶿﷀﷁﷂﷃﷄﷅﷆﷇ﷈﷉﷊﷋﷌﷍﷎﷏ﷰﷱﷲﷳﷴﷵﷶﷷﷸﷹﷺﷻ ً الحجرات: ٨

DEDICATION

To

My mother,

My father's soul,

My kids, Abdurrahman and Fatimah,

My sisters and brothers,

My family,

My friends

To all who help me during my research.

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ABSTRACT

This research aimed to study a model of laser cooling and trapping of radium atoms and developing a system of governing equations in similar way to the well-known four-levels Maxwell Bloch system, and to present computational results for special solutions of four levels system along with steps for how this system can been cooled by laser using MATLAB program.

The theory includes the mechanical light effect for atomic structure. The atomic decay time derived was determined according to the photon account. In this work MATLAB simulation of the atomic Liouville equation for spontaneous emissions was developed for laser cooling of radium atoms. The study followed the simulating solution of optical Bloch equations (OBEs) for four level system in an atom trap. Where the center of mass motion is described quantum mechanically.

The results showed that the laser cooling approach to Maxwell's law, the reduction of the velocity leads to new distribution of velocities and the atoms moving towards the light source will resonate the light field (crossing resonance).

In future, theoretical analysis shows that laser photons used for cooling atoms have velocity distribution that could be used to study many-body physics.

الخلاصة

يهدف هذا البحث إلى دراسة نموذج تقنية التبريد بالليزر واصطياد ذرات عنصر الراديوم وتوضيح النظام بمعادلات ماكسويل بلوخ ذي الأربع مستويات المعروفة، وتقديم نتائج حسابية لحلول معادلات بلوخ في المستويات الأربعة لليزر باستخدام برنامج الماتلاب.

تضمن الجانب النظري تأثير حركة الليزر وتأثيره على التركيب الذري للراديوم. تم تحديد وقت الاضمحلال الذري وفقا لحساب عدد الفوتونات.وبينت الدراسة المحاكاة بواسطة برنامج الماتلاب بتطوير معادلات ليفويئل للانبعاثات التلقائية. اتبعت الدراسة حل محاكاة معادلات بلوخ البصرية (OBEs) لنظام أربعة مستويات في مصيدة الذرة. حيث يتم وصف مركز حركة الذرات ميكانيكياً .وأظهرت النتائج أن التبريد بالليزر لقانون ماكسويل، يؤدي تخفيض السرعة إلى توزيع جديد للسرعات، وتتحرك الذرات نحو مصدر ضوء الليزر يؤدي الى (رنين) .

في المستقبل، يُظهر التحليل النظري أن فوتونات الليزر المستخدمة لذرات التبريد لها توزيع سرعات يمكن استخدامه لدراسات كثيرة في عالم الفيزياء.

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