



1. Introduction

elsarticle.cls is a thoroughly re-written document class for formatting L^AT_EX submissions to Elsevier journals. The class uses the environments and commands defined in L^AT_EX kernel without change to the signature so that clashes with other contributed L^AT_EX packages like hyperref.sty, preview-latex.sty, etc., will be minimal. elsarticle.cls is primarily built upon the default article.cls. The class depends on the following packages for its proper functionality:

1. pifont.sty for openstar in the title footnotes.
2. natbib.sty for citation processing.
3. geometry.sty for margin settings.
4. fleqn.clo for left aligned equations.
5. graphicx.sty for graphics inclusion.
6. txfonts.sty optional font package, if document is to be formatted with Times and compatible math fonts.
7. hyperref.sty optional packages if hyper linking is required in the document.

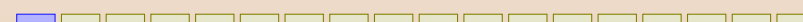
All the above packages are part of any standard L^AT_EX installation. Therefore, the users need not be bothered about downloading any extra packages. Further, users are free to make use of AMS math packages like, amsmath.sty, amsthm.sty, amssymb.sty, amsfonts.sty, etc., if they want. All these packages work in tandem with elsarticle.cls without any problems.

2. Major Differences

Following are the major differences between elsarticle.cls and its predecessor package, elsart.cls:

- Introduction
- Major Differences
- Installation
- Usage
- Preamble
- Floats
- Theorems
- Lists
- Cross-references
- Mathematical Symbols and Formulae
- Bibliography
- Final Print

©2008, Elsevier Ltd. Bugs, feature requests, suggestions and comments shall be mailed to <elsarticle@river-valley.com>. elsarticle.[dtx,ins], related documentation and supporting packages are released under L^AT_EX Project Public Licence, either version 1.2 or any later version. This work has the LPPL maintenance status 'author-maintained'.





- elsarticle.cls is built upon article.cls while elsart.cls is not. elsart.cls redefines many of the commands in the L^AT_EX classes/kernel, which can possibly cause surprising clashes with other contributed L^AT_EX packages.
- Provides preprint document formatting by default, and optionally formats the document as per the final style of models 1+, 3+ and 5+ of Elsevier journals.
- Some easier hooks for formatting `list` and `theorem` environments are provided while people can still use amsthm.sty package.
- natbib.sty is the main citation processing package which can comprehensively handle all kinds of citations and works perfectly with hyperref.sty in combination with hypernat.sty.
- Long title pages are processed correctly in preprint and final formats.

3. Installation

The package is available at <http://www.elsevier.com/locate/latex>. It can also be found in any of the nodes of the Comprehensive T_EX Archive Network (CTAN), one of the primary nodes being <http://www.ctan.org/tex-archive/macros/latex/contrib/elsevier/>. Please grab the elsarticle.dtx which is the composite class with documentation and elsarticle.ins which is the L^AT_EX installer file. When we compile the elsarticle.ins with L^AT_EX it provides the class file, elsarticle.cls by stripping off all the documentation from the *.dtx file. The class may be moved or copied to a place, usually, \$TEXMF/tex/latex/elsevier/, or a folder which will be read by L^AT_EX during document compilation. The T_EX file database needs update after moving/copying class file. Usually, we use commands like mktexlsr or texhash depending upon the distribution and operating system.

- Introduction
- Major Differences
- Installation
- Usage
- Preamble
- Floats
- Theorems
- Lists
- Cross-references
- Mathematical Symbols and Formulae
- Bibliography
- Final Print

©2008, Elsevier Ltd. Bugs, feature requests, suggestions and comments shall be mailed to <elsarticle@river-valley.com>. elsarticle.[dtx,ins], related documentation and supporting packages are released under L^AT_EX Project Public Licence, either version 1.2 or any later version. This work has the LPPL maintenance status 'author-maintained'.





4. Usage

The class should be loaded with the command:

```
\documentclass[<options>]{elsarticle}
```

where the **options** can be the following:

- (1) **preprint** — default options which formats the document for submission to Elsevier journals.
- (2) **review** — similar to **preprint** option, but increases the baselineskip to facilitate easier review process.
- (3) **1p** — formats to the look and feel of the final format of model 1+ journals. This is always single column style.
- (4) **3p** — formats to the look and feel of the final format of model 3+ journals. If the journal is a two column model use **twocolumn** option in combination.
- (5) **5p** — formats for model 5+ journals. This is always two column style.
- (6) **authoryear** — author-year citation style of natbib.sty. If you want to add extra options of natbib.sty, you may use the options as a comma delimited strings as argument to **\biboptions** command. An example would be:

```
\biboptions{longnamesfirst,angle,semicolon}
```

- (7) **number** — numbered citation style. Extra options can be loaded with **\biboptions** command.
- (8) **longtitle** — if front matter is unusually long, use this option to split the title page across pages with correct placing of title and author footnotes in the first page.

- Introduction
- Major Differences
- Installation
- Usage
- Preamble
- Floats
- Theorems
- Lists
- Cross-references
- Mathematical Symbols and Formulae
- Bibliography
- Final Print

©2008, Elsevier Ltd. Bugs, feature requests, suggestions and comments shall be mailed to <elsarticle@river-valley.com>. elsarticle.[dtx,ins], related documentation and supporting packages are released under L^AT_EX Project Public Licence, either version 1.2 or any later version. This work has the LPPL maintenance status ‘author-maintained’.





- (9) `times` — loads `txfonts.sty` if available in the system to use Times and compatible math fonts.
- (10) All options of `article.cls` can be used with this document class.
- (11) The default options loaded are `a4paper`, `10pt`, `oneside`, `onecolumn` and `preprint`.

5. Preamble

There are two types of preamble coding — (1) each author is connected to an affiliation with a footnote marker; hence all authors are grouped together and affiliations follow; (2) authors of same affiliations are grouped together and the relevant affiliation follows this group. An example coding of the first type is provided below:

```
\title{This is a specimen title\tnoteref{t1,t2}}  
\tnotetext[t1]{This document is a collaborative effort.}  
\tnotetext[t2]{The second title footnote which is a longer  
longer than the first one and with an intention to fill  
in up more than one line while formatting.}
```

- Introduction
- Major Differences
- Installation
- Usage
- Preamble
- Floats
- Theorems
- Lists
- Cross-references
- Mathematical Symbols and Formulae
- Bibliography
- Final Print

©2008, Elsevier Ltd. Bugs, feature requests, suggestions and comments shall be mailed to elsarticle@river-valley.com. `elsarticle`, `[dtx,ins]`, related documentation and supporting packages are released under L^AT_EX Project Public Licence, either version 1.2 or any later version. This work has the LPPL maintenance status ‘author-maintained’.





```
\author[rvt]{C.V.~Radhakrishnan\corref{cor1}\fnref{fn1}}  
\ead{cvr@river-valley.com}
```

```
\author[rvt,focal]{K.~Bazargan\fnref{fn2}}  
\ead{kaveh@river-valley.com}
```

```
\author[els]{S.~Pepping\corref{cor2}\fnref{fn1,fn3}}  
\ead[url]{http://www.elsevier.com}
```

```
\cortext[cor1]{Corresponding author}  
\cortext[cor2]{Principal corresponding author}  
\fntext[fn1]{This is the specimen author footnote.}  
\fntext[fn2]{Another author footnote, but a little more longer.}  
\fntext[fn3]{Yet another author footnote. Indeed, you can have  
any number of author footnotes.}
```

```
\address[rvt]{River Valley Technologies, SJP Building,  
Cotton Hills, Trivandrum, Kerala, India 695014}  
\address[focal]{River Valley Technologies, 9, Browns Court,  
Kennford, Exeter, United Kingdom}  
\address[els]{Central Application Management,  
Elsevier, Radarweg 29, 1043 NX\\  
Amsterdam, Netherlands}
```

This is a specimen title^{☆,☆☆}

C.V. Radhakrishnan^{a,*,1}, K. Bazargan^{a,b,2}, S. Pepping^{c,*,1,3}

^aRiver Valley Technologies, SJP Building, Cotton Hills, Trivandrum, Kerala, India 695014

^bRiver Valley Technologies, 9, Browns Court, Kennford, Exeter, United Kingdom

^cCentral Application Management, Elsevier, Radarweg 29, 1043 NX
Amsterdam, Netherlands

Abstract

In this work we demonstrate the formation of a new type of polariton on the interface between a cuprous oxide slab and a polystyrene micro-sphere placed on the slab. The evanescent field of the resonant whispering gallery mode (WGM) of the micro sphere has a substantial gradient, and therefore effectively couples with the quadrupole 1S excitons in cuprous oxide. This evanescent polariton has a long life-time, which is determined only by its excitonic and WGM component. The polariton lower branch has a well pronounced minimum. This suggests that this excitation is localized and can be utilized for possible BEC. The spatial coherence of the polariton can be improved by assembling the micro-spheres into a linear chain.

Key words: quadrupole exciton, polariton, WGM, BEC

PACS: 71.35.-y, 71.35.Lk, 71.36.+c

1. Introduction

Although quadrupole excitons (QE) in cuprous oxide crystals are good candidates for BEC due to their narrow line-width and long life-time there are some factors impeding BEC Kavoulakis and Baym (1996); Roslyak and Birman (2007). One of these factors is that due to the small but non negligible coupling

[☆]This document is a collaborative effort.

^{☆☆}The second title footnote which is a longer longer than the first one and with an intention to fill in up more than one line while formatting.

^{*}Corresponding author

^{**}Principal corresponding author

Email addresses: cvr@river-valley.com (C.V. Radhakrishnan),

kaveh@river-valley.com (K. Bazargan)

URL: http://www.elsevier.com (S. Pepping)

¹This is the specimen author footnote.

²Another author footnote, but a little more longer.

³Yet another author footnote. Indeed, you can have any number of author footnotes.

You can see the output in the panel to the right.



Most of the commands like `\title`, `\author`, `\address` are self explanatory. Various components are linked each other by a label–reference mechanism, for instance, title footnote is linked to the title with a footnote mark generated by referring to the `\label` string of the `\tnotetext`. We have used similar commands like `\tnoteref` (to link title note to title); `\corref` (to link corresponding author text to corresponding author); `\fnref` (to link footnote text to the relevant author names). \TeX needs two compilations to resolve the footnote marks in the preamble part. Given below are the syntax of various note marks and note texts.

```
\tnoteref{<label(s)>}
\corref{<label(s)>}
\fnref{<label(s)>}
\tnotetext[<label>]{<title note text>}
\cortext[<label>]{<corresponding author note text>}
\fnctext[<label>]{<author footnote text>}
```

where `<label(s)>` can be either one or more comma delimited label strings. The optional arguments to the `\author` command holds the ref label(s) of the address(es) to which the author is affiliated while each `\address` command can have an optional argument of a label. In the same manner, `\tnotetext`, `\fnctext`, `\cortext` will have optional arguments as their respective labels and note text as their mandatory argument.

The following example code provides the markup of the second type of author-affiliation as seen in the output given in the box to the right.

This is a specimen title^{☆,☆☆}

C.V. Radhakrishnan^{*1}

River Valley Technologies, SJP Building, Cotton Hills, Trivandrum, Kerala, India 695014

K. Bazargan²

River Valley Technologies, 9, Browns Court, Kennford, Exeter, United Kingdom

S. Pepping^{1,3}

*Central Application Management, Elsevier, Radarweg 29, 1043 NX
Amsterdam, Netherlands*

Abstract

In this work we demonstrate the formation of a new type of polariton on the interface between a cuprous oxide slab and a polystyrene micro-sphere placed on the slab. The evanescent field of the resonant whispering gallery mode (WGM) of the micro sphere has a substantial gradient, and therefore effectively couples with the quadrupole 1S excitons in cuprous oxide. This evanescent polariton has a long life-time, which is determined only by its excitonic and WGM component. The polariton lower branch has a well pronounced minimum. This suggests that this excitation is localized and can be utilized for possible BEC. The spatial coherence of the polariton can be improved by assembling the micro-spheres into a linear chain.

Key words: quadrupole exciton, polariton, WGM, BEC

PACS: 71.35.-y, 71.35.Lk, 71.36.+c

[☆]This document is a collaborative effort.

^{☆☆}The second title footnote which is a longer longer than the first one and with an intention to fill in up more than one line while formatting.

^{*}Corresponding author

Email addresses: cvr@river-valley.com (C.V. Radhakrishnan),

kaveh@river-valley.com (K. Bazargan)

URL: <http://www.elsevier.com> (S. Pepping)

¹This is the first author footnote.

²Another author footnote, this is a very long footnote and it should be a really long footnote. But this footnote is not yet sufficiently long enough to make two lines of footnote text.

³Yet another author footnote.



```
\author{C.V.~Radhakrishnan\corref{cor1}\fnref{fn1}}  
\ead{cvr@river-valley.com}  
\address{River Valley Technologies, SJP Building,  
Cotton Hills, Trivandrum, Kerala, India 695014}
```

```
\author{K.~Bazargan\fnref{fn2}}  
\ead{kaveh@river-valley.com}  
\address{River Valley Technologies, 9, Browns Court, Kennford,  
Exeter, UK.}
```

```
\author{S.~Pepping\fnref{fn1,fn3}}  
\ead[url]{http://www.elsevier.com}  
\address{Central Application Management,  
Elsevier, Radarweg 43, 1043 NX Amsterdam, Netherlands}
```

```
\cortext[cor1]{Corresponding author}  
\fntext[fn1]{This is the first author footnote.}  
\fntext[fn2]{Another author footnote, this is a very long footnote and  
it should be a really long footnote. But this footnote is not yet  
sufficiently long enough to make two lines of footnote text.}  
\fntext[fn3]{Yet another author footnote.}
```

The preamble part has further environments like `\begin{abstract} ... \end{abstract}` and `\begin{keyword} ... \end{keyword}` which contain the

This is a specimen title^{☆,☆☆}

C.V. Radhakrishnan^{*1}

River Valley Technologies, SJP Building, Cotton Hills, Trivandrum, Kerala, India 695014

K. Bazargan²

River Valley Technologies, 9, Browns Court, Kennford, Exeter, United Kingdom

S. Pepping^{1,3}

*Central Application Management, Elsevier, Radarweg 29, 1043 NX
Amsterdam, Netherlands*

Abstract

In this work we demonstrate the formation of a new type of polariton on the interface between a cuprous oxide slab and a polystyrene micro-sphere placed on the slab. The evanescent field of the resonant whispering gallery mode (WGM) of the micro sphere has a substantial gradient, and therefore effectively couples with the quadrupole 1S excitons in cuprous oxide. This evanescent polariton has a long life-time, which is determined only by its excitonic and WGM component. The polariton lower branch has a well pronounced minimum. This suggests that this excitation is localized and can be utilized for possible BEC. The spatial coherence of the polariton can be improved by assembling the micro-spheres into a linear chain.

Key words: quadrupole exciton, polariton, WGM, BEC

PACS: 71.35.-y, 71.35.Lk, 71.36.+c

[☆]This document is a collaborative effort.

^{☆☆}The second title footnote which is a longer longer than the first one and with an intention to fill in up more than one line while formatting.

^{*}Corresponding author

Email addresses: cvr@river-valley.com (C.V. Radhakrishnan),

kaveh@river-valley.com (K. Bazargan)

URL: http://www.elsevier.com (S. Pepping)

¹This is the first author footnote.

²Another author footnote, this is a very long footnote and it should be a really long footnote. But this footnote is not yet sufficiently long enough to make two lines of footnote text.

³Yet another author footnote.



abstract and keywords respectively. Keywords can be marked up in the following manner:

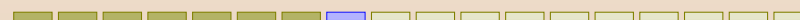
```
\begin{keyword}
quadruple exciton \sep polariton \sep WGM

\PACS 71.35.-y \sep 71.35.Lk \sep 71.36.+c
\end{keyword}
```

Each keyword shall be separated by `\sep` command. PACS and MSC classifications shall be provided in the keyword environment with the commands `\PACS` and `\MSC` respectively. `\MSC` accepts an optional argument to accommodate future revisions. eg., `\MSC[2008]`. The default is 2000.

- Introduction
- Major Differences
- Installation
- Usage
- Preamble
- Floats
- Theorems
- Lists
- Cross-references
- Mathematical Symbols and Formulae
- Bibliography
- Final Print

©2008, Elsevier Ltd. Bugs, feature requests, suggestions and comments shall be mailed to elsarticle@river-valley.com. elsarticle.[dtx,ins], related documentation and supporting packages are released under L^AT_EX Project Public Licence, either version 1.2 or any later version. This work has the LPPL maintenance status ‘author-maintained’.







Users can also make use of `amsthm.sty` which will override all the default definitions described above.

elsarticle.cls provides an extended list processing macros which makes the usage a bit more user friendly than the default L^AT_EX list macros. With an optional argument to the `\begin{enumerate}` command, you can change the list counter type and its attributes.

- Introduction
- Major Differences
- Installation
- Usage
- Preamble
- Floats
- Theorems
- Lists
- Cross-references
- Mathematical Symbols and Formulae
- Bibliography
- Final Print

©2008, Elsevier Ltd. Bugs, feature requests, suggestions and comments shall be mailed to elsarticle@river-valley.com. elsarticle. [dtx,ins], related documentation and supporting packages are released under L^AT_EX Project Public Licence, either version 1.2 or any later version. This work has the LPPL maintenance status ‘author-maintained’.





```
\begin{enumerate}[a]
  \item Another level of list with alphabetical counter.
  \item One more item before we start another.
  \begin{enumerate}[(i)]
    \item This item has roman numeral counter.
    \item Another one before we close the third level.
  \end{enumerate}
  \item Third item in second level.
\end{enumerate}
\item All list items conclude with this step.
\end{enumerate}
```

You can see the typeset copy of the above source code if you roll over `zobraz(mytip4);zobraz(mytip4);zobraz(mytip4);zobraz(mytip4);zobraz(mytip4);zobraz(mytip4);`

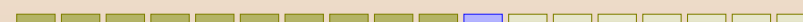
Further, the enhanced list environment allows one to prefix a string like ‘step’ to all the item numbers. Take a look at the example below:

```
\begin{enumerate}[Step 1.]
  \item This is the first step of the example list.
  \item Obviously this is the second step.
  \item The final step to wind up this example.
\end{enumerate}
```

`zobraz(mytip5);zobraz(mytip5);zobraz(mytip5);zobraz(mytip5);zobraz(mytip5);zobraz(mytip5);`

- Introduction
- Major Differences
- Installation
- Usage
- Preamble
- Floats
- Theorems
- Lists
- Cross-references
- Mathematical Symbols and Formulae
- Bibliography
- Final Print

©2008, Elsevier Ltd. Bugs, feature requests, suggestions and comments shall be mailed to <elsarticle@river-valley.com>. elsarticle, [tex,ms], related documentation and supporting packages are released under L^AT_EX Project Public Licence, either version 1.2 or any later version. This work has the LPPL maintenance status ‘author-maintained’.





©2008, Elsevier Ltd. Bugs, feature requests, suggestions and comments shall be mailed to elsarticle@river-valley.com. elsarticle. [dtx,ins], related documentation and supporting packages are released under L^AT_EX Project Public Licence, either version 1.2 or any later version. This work has the LPPL maintenance status ‘author-maintained’.





loading command, which is explained in section ??, ??. This allows authors to fix any equation breaking problem before submission for publication. `elsarticle.cls` supports formatting the author submission in different types of final format. This is further discussed in section ??, ??.

11. Bibliography

Three bibliographic style files (`*.bst`) are provided — `elsarticle-num.bst`, `elsarticle-num-names.bst` and `elsarticle-harv.bst` — the first one for numbered scheme, the second for numbered with new options of `natbib.sty` and the last one for author year scheme.

In \LaTeX literature references are listed in the `thebibliography` environment. Each reference is a `\bibitem`; each `\bibitem` is identified by a label, by which it can be cited in the text: `\bibitem[Elson et al.(1996)]{ESG96}` is cited as `\citet{ESG96}`. In connection with cross-referencing and possible future hyperlinking it is not a good idea to collect more than one literature item in one `\bibitem`. The so-called Harvard or author-year style of referencing is enabled by the \LaTeX package `natbib`. With this package the literature can be cited as follows:

- Parenthetical: `\citep{WB96}` produces (Wettig & Brown, 1996).
- Textual: `\citet{ESG96}` produces Elson et al. (1996).
- An affix and part of a reference: `\citep[e.g.][Ch. 2]{Gea97}` produces (e.g. Governato et al., 1997, Ch. 2).

In the numbered scheme of citation, `\cite{<label>}` is used, since `\citep` or `\citet` has no relevance in numbered scheme. `natbib` package is loaded by `elsarticle` with `numbers` as default option. You can change this to author-year or harvard scheme by adding option `authoryear` in the class loading command. If you want to use more options of the `natbib` package, you can do so with

- Introduction
- Major Differences
- Installation
- Usage
- Preamble
- Floats
- Theorems
- Lists
- Cross-references
- Mathematical Symbols and Formulae
- Bibliography
- Final Print

©2008, Elsevier Ltd. Bugs, feature requests, suggestions and comments shall be mailed to elsarticle@river-valley.com. `elsarticle`.
[dtx,ins], related documentation and supporting packages are released under \LaTeX Project Public Licence, either version 1.2 or any later version. This work has the LPPL maintenance status ‘author-maintained’.

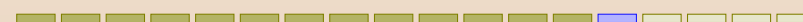




the `\biboptions` command, which is described in section ??, ??. For details of various options of the `natbib` package, please take a look at the `natbib` documentation, which is part of any standard \LaTeX installation.

- [Introduction](#)
- [Major Differences](#)
- [Installation](#)
- [Usage](#)
- [Preamble](#)
- [Floats](#)
- [Theorems](#)
- [Lists](#)
- [Cross-references](#)
- [Mathematical Symbols and Formulae](#)
- [Bibliography](#)
- [Final Print](#)

©2008, Elsevier Ltd. Bugs, feature requests, suggestions and comments shall be mailed to [<elsarticle@river-valley.com>](mailto:elsarticle@river-valley.com). `elsarticle`, `[dtx,ins]`, related documentation and supporting packages are released under \LaTeX Project Public Licence, either version 1.2 or any later version. This work has the LPPL maintenance status ‘author-maintained’.





12. Final print

Authors can format their submission to the page size and margins of their preferred journal. elsarticle provides four class options for the same:

1p: 1+ journals with a text area of 384pt × 562pt or 13.5cm × 19.75cm or 5.3in × 7.78in, single column style only.

3p: 3+ journals with a text area of 468pt × 622pt or 16.45cm × 21.9cm or 6.5in × 8.6in, single column style.

3pd: 3+ with the same text area as above, double column style.

5p: 5+ with text area of 522pt × 682pt or 18.35cm × 24cm or 7.22in × 9.45in, double column style only.

Following pages have the clippings of different parts of the first page of different journal models typeset in final format.

Clip 1: Upper part of first page of a single column article.

This is a specimen title^{☆,☆☆}

C.V. Radhakrishnan^{a,*,1}, K. Bazargan^{a,b,2}, S. Pepping^{c,**,1,3}

^aRiver Valley Technologies, SJP Building, Cotton Hills, Trivandrum, Kerala, India 695014

^bRiver Valley Technologies, 9, Browns Court, Kennford, Exeter, United Kingdom

^cCentral Application Management, Elsevier, Radarweg 29, 1043 NX
Amsterdam, Netherlands

Abstract

In this work we demonstrate the formation of a new type of polariton on the interface between a cuprous oxide slab and a polystyrene micro-sphere placed on the slab. The evanescent field of the resonant whispering gallery mode (WGM) of the micro sphere has a substantial gradient, and

- Introduction
- Major Differences
- Installation
- Usage
- Preamble
- Floats
- Theorems
- Lists
- Cross-references
- Mathematical Symbols and Formulae
- Bibliography
- Final Print

©2008, Elsevier Ltd. Bugs, feature requests, suggestions and comments shall be mailed to <elsarticle@river-valley.com>. elsarticle. [dtx,ins], related documentation and supporting packages are released under L^AT_EX Project Public Licence, either version 1.2 or any later version. This work has the LPPL maintenance status ‘author-maintained’.



**Clip 2: Lower part of first page of a single column article.**

Key words: quadrupole exciton, polariton, WGM, BEC

PACS: 71.35.-y, 71.35.Lk, 71.36.+c

1. Introduction

Although quadrupole excitons (QE) in cuprous oxide crystals are good candidates for BEC due to their narrow line-width and long life-time there are some factors impeding BEC [Kavoulakis and Baym \(1996\)](#); [Roslyak and Birman \(2007\)](#). One of these factors is that due to the small but non negligible coupling to the photon bath, one must consider BEC of the corresponding mixed light-matter states called polaritons [Frohlich et al. \(2005\)](#). The photon-like part of the polariton has a large group velocity and tends to escape from the crystal. Thus, the temporal coherence of the condensate is effectively broken [Ell et al. \(1998\)](#); [Snoke \(2002\)](#). One proposed solution to

☆This document is a collaborative effort.

☆☆The second title footnote which is a longer longer than the first one and with an intention to fill in up more than one line while formatting.

*Corresponding author

**Principal corresponding author

Email addresses: cvr@river-valley.com (C.V. Radhakrishnan), kaveh@river-valley.com (K. Bazargan)

URL: <http://www.elsevier.com> (S. Pepping)

¹This is the specimen author footnote.

²Another author footnote, but a little more longer.

³Yet another author footnote. Indeed, you can have any number of author footnotes.

Preprint submitted to Elsevier

February 14, 2008

Model 1+ and 3+ will have the same look and feel in the typeset copy when presented in this document. That is also the case with the double column 3+ and 5+ journal article pages. The only difference will be wider text width of higher models. Therefore we will look at the different portions of a typical single column journal page and that of a double column article in the final format.

- Introduction
- Major Differences
- Installation
- Usage
- Preamble
- Floats
- Theorems
- Lists
- Cross-references
- Mathematical Symbols and Formulae
- Bibliography
- Final Print

©2008, Elsevier Ltd. Bugs, feature requests, suggestions and comments shall be mailed to [<elsarticle@river-valley.com>](mailto:elsarticle@river-valley.com). elsarticle. [dtx,ins], related documentation and supporting packages are released under L^AT_EX Project Public Licence, either version 1.2 or any later version. This work has the LPPL maintenance status ‘author-maintained’.



Clip 3: Upper part of first page of a typical double column article.

This is a specimen title^{☆,☆☆}

C.V. Radhakrishnan^{a,*,1}, K. Bazargan^{a,b,2}, S. Pepping^{c,*,1,3}

^a*River Valley Technologies, SJP Building, Cotton Hills, Trivandrum, Kerala, India 695014*

^b*River Valley Technologies, 9, Browns Court, Kennford, Exeter, United Kingdom*

^c*Central Application Management, Elsevier, Radarweg 29, 1043 NX
Amsterdam, Netherlands*

Abstract

In this work we demonstrate the formation of a new type of polariton on the interface between a cuprous oxide slab and a polystyrene micro-sphere placed on the slab. The evanescent field of the resonant whispering gallery mode (WGM) of the micro sphere has a substantial gradient, and therefore effectively couples with the quadrupole 1S excitons in cuprous oxide. This evanescent polariton has a long life-time, which is determined only by its excitonic and WGM component. The polariton lower branch has a well pronounced minimum. This suggests that this excitation is localized and can be utilized for possible BEC. The spatial coherence of the polariton can be improved by assembling the micro-spheres into a linear chain.

Key words: quadrupole exciton, polariton, WGM, BEC

PACS: 71.35.-y, 71.35.Lk, 71.36.+c

1. Introduction

Although quadrupole excitons (QE) in cuprous oxide crystals are good candidates for BEC due to their narrow line-width and long life-time there are some factors impeding BEC Kavoulakis and Baym (1996); Roslyak and Birman (2007). One of these factors is that due to the small but non negligible coupling to the photon bath, one must consider BEC of the corresponding mixed light-matter states called polaritons Frohlich et al. (2005). The photon-like part of the polariton has a large group velocity and tends to escape from the crystal. Thus, the temporal coherence of the condensate is effectively broken Ell et al. (1998); Snoke (2002). One

proposed solution to this issue is to place the crystal into a planar micro-cavity Kasprzak et al. (2006). But even state-of-the-art planar micro-cavities can hold the light no longer than $10 \mu s$. Besides, formation of the polaritons in the planar cuprous oxide micro-cavity is not effective due to quadrupole origin of the excitons.

Therefore in this work we propose to prevent the polariton escaping by trapping it into a whispering gallery mode (WGM)⁴ of a polystyrene micro-sphere (PMS).

We develop a model which demonstrates formation of a strongly localized polariton-like quasi-particle. This quasi-particle is formed by the resonant interaction between the WGM in PMS and QE in the adjacent layer of cuprous oxide. The QE interacts with the gradient of the WGM evanescent field

- Introduction
- Major Differences
- Installation
- Usage
- Preamble
- Floats
- Theorems
- Lists
- Cross-references
- Mathematical Symbols and Formulae
- Bibliography
- Final Print

©2008, Elsevier Ltd. Bugs, feature requests, suggestions and comments shall be mailed to <elsarticle@river-valley.com>. elsarticle.[dtx,ins], related documentation and supporting packages are released under L^AT_EX Project Public Licence, either version 1.2 or any later version. This work has the LPPL maintenance status ‘author-maintained’.





Clip 4: Lower part of first page a typical double column article.

Abstract

In this work we demonstrate the formation of a new type of polariton on the interface between a cuprous oxide slab and a polystyrene micro-sphere placed on the slab. The evanescent field of the resonant whispering gallery mode (WGM) of the micro sphere has a substantial gradient, and therefore effectively couples with the quadrupole $1S$ excitons in cuprous oxide. This evanescent polariton has a long life-time, which is determined only by its excitonic and WGM component. The polariton lower branch has a well pronounced minimum. This suggests that this excitation is localized and can be utilized for possible BEC. The spatial coherence of the polariton can be improved by assembling the micro-spheres into a linear chain.

Key words: quadrupole exciton, polariton, WGM, BEC

PACS: 71.35.-y, 71.35.Lk, 71.36.+c

1. Introduction

Although quadrupole excitons (QE) in cuprous oxide crystals are good candidates for BEC due to their narrow line-width and long life-time there are some factors impeding BEC [Kavoulakis and Baym \(1996\)](#); [Roslyak and Birman \(2007\)](#). One of these factors is that due to the small but non negligible coupling to the photon bath, one must consider BEC of the corresponding mixed light-matter states called polaritons [Frohlich et al. \(2005\)](#). The photon-like part of the polariton has a large group velocity and tends to escape from the crystal. Thus, the temporal coherence of the condensate is effectively broken [Ell et al. \(1998\)](#); [Snoke \(2002\)](#). One

proposed solution to this issue is to place the crystal into a planar micro-cavity [Kasprzak et al. \(2006\)](#). But even state-of-the-art planar micro-cavities can hold the light no longer than $10\ \mu s$. Besides, formation of the polaritons in the planar cuprous oxide micro-cavity is not effective due to quadrupole origin of the excitons.

Therefore in this work we propose to prevent the polariton escaping by trapping it into a whispering gallery mode (WGM)⁴ of a polystyrene micro-sphere (PMS).

We develop a model which demonstrates formation of a strongly *localized* polariton-like quasi-particle. This quasi-particle is formed by the *resonant* interaction between the WGM in PMS and QE in the adjacent layer of cuprous oxide. The QE interacts with the *gradient* of the WGM evanescent field.

There are few experiments concerned with resonant interaction of the WGM and dipole allowed exciton (DE) [Xudong Fan \(1999\)](#); [Fan et al. \(1999\)](#). But the DE has some disadvantages compared to QE when it comes to interaction with the WGM. First, the evanescent light has small intensity. Therefore it is not effective for the

^{*}This document is a collaborative effort.

^{☆☆}The second title footnote which is a longer longer than the first one and with an intention to fill in up more than one line while formatting.

^{*}Corresponding author

^{**}Principal corresponding author

Email addresses: cvr@river-valley.com (C.V. Radhakrishnan), kaveh@river-valley.com (K. Bazargan)
URL: <http://www.elsevier.com> (S. Pepping)

¹This is the specimen author footnote.

²Another author footnote, but a little more longer.

³Yet another author footnote. Indeed, you can have any number of author footnotes.

Preprint submitted to Elsevier

⁴ WGM occur at particular resonant wavelengths of light for a given dielectric sphere size. At these wavelengths, the light undergoes total internal reflection at the sphere surface and becomes trapped within the particle for timescales of the order of ns .

February 14, 2008

- Introduction
- Major Differences
- Installation
- Usage
- Preamble
- Floats
- Theorems
- Lists
- Cross-references
- Mathematical Symbols and Formulae
- Bibliography
- Final Print

©2008, Elsevier Ltd. Bugs, feature requests, suggestions and comments shall be mailed to elsarticle@river-valley.com. elsarticle. [dtx,ins], related documentation and supporting packages are released under L^AT_EX Project Public Licence, either version 1.2 or any later version. This work has the LPPL maintenance status 'author-maintained'.



Displayed equations and double column journals

Many Elsevier journals print their text in two columns. Because the preprint layout uses a larger line width than such columns, the formulas are too wide for the line width in print. Here is an example of an equation (see equation 6) which is perfect in single column preprint format:

Clip 5: See equation (6).

$$\mathbf{M}_{1,39} = A_{1,39}^{ml} (r_0 + \delta r) \mathbf{M}_{ml} + B_{1,39}^{ml} (r_0 + \delta r) \mathbf{N}_{ml} \quad (4)$$

Here $A_{1,39}^{ml}$ and $B_{1,39}^{ml}$ are the translational coefficients. Their explicit expression can be found, for instance, in [Fuller \(1991\)](#); [Miyazaki and Jimba \(2000\)](#) and are explicitly listed in the Appendix.

The bulk (incident) and evanescent polaritons in cuprous oxide are formed through the quadrupole part of the light-matter interaction:

$$\mathbf{M}_{1,39} = A_{1,39}^{ml} (r_0 + \delta r) \mathbf{M}_{ml} + B_{1,39}^{ml} (r_0 + \delta r) \mathbf{N}_{ml} \quad (5)$$

Here e, m are the electron charge and mass; \mathbf{p} is the electron momentum. For the quadrupole $1S$ transition in cuprous oxide the energy of interaction can be written as:

$$\sum_{i=0}^{\infty} A^n \int dx \frac{F_n(x)}{A_n + B_n} = B^n C^n \int dx \int dy \frac{G_n(x, y)}{\mathcal{A}_n x + \mathcal{B}_n y} + \frac{G_n(x, y)}{\mathcal{A}_n x + \mathcal{B}_n y} \quad (6)$$

When this document is typeset for publication in a model 3+ journal with double columns, the equation will overlap the second column text matter if the equation is not broken at the appropriate location.

- Introduction
- Major Differences
- Installation
- Usage
- Preamble
- Floats
- Theorems
- Lists
- Cross-references
- Mathematical Symbols and Formulae
- Bibliography
- Final Print

©2008, Elsevier Ltd. Bugs, feature requests, suggestions and comments shall be mailed to <elsarticle@river-valley.com>. elsarticle. [dtx,ins], related documentation and supporting packages are released under L^AT_EX Project Public Licence, either version 1.2 or any later version. This work has the LPPL maintenance status ‘author-maintained’.



Clip 6: See equation (6) overprints into second column.

Fuller (1991); Miyazaki and Jimba (2000) and are explicitly listed in the Appendix.

The bulk (incident) and evanescent polaritons in cuprous oxide are formed through the quadrupole part of the light-matter interaction:

$$\mathbf{M}_{1,39} = A_{1,39}^{ml} (r_0 + \delta r) \mathbf{M}_{ml} + B_{1,39}^{ml} (r_0 + \delta r) \mathbf{N}_{ml} \quad (5)$$

Here e , m are the electron charge and mass; \mathbf{p} is the electron momentum. For the quadrupole $1S$ transition in cuprous oxide the energy of interaction can be written as:

$$\sum_{i=0}^{\infty} A^n \int dx \frac{F_n(x)}{A_n + B_n} = B^n C^n \int dx \int dy \frac{G_n(x, y)}{\mathcal{A}_n x + \mathcal{B}_n y} + \frac{G_n(x, y)}{\mathcal{A}_n x + \mathcal{B}_n y} \quad (6)$$

Here we introduced the initial state of the system, which

penetrating into cuprous oxide, although the coupling grows with mode number l , because the gradient of the evanescent field increases. Note that QE realizes *strong* coupling regime $g_{1,39} > \gamma$ while DE demonstrates *weak* regime only Xudong Fan (1999). The property of the scalable coupling factor can be utilized in practical applications such as non-linear optics and is the subject of our future work.

3. Results and discussion

In this section let us utilize the above calculated WQM-QE interaction to obtain the evanescent polariton dispersion in the framework of the coupled oscillator model that has been widely used for describing coupled atom-photon or exciton-photon modes in micro-

- Introduction
- Major Differences
- Installation
- Usage
- Preamble
- Floats
- Theorems
- Lists
- Cross-references
- Mathematical Symbols and Formulae
- Bibliography
- Final Print

The typesetter will try to break the equation which need not necessarily be to the liking of the author or as it happens, typesetter's break point may be semantically incorrect. Therefore, authors may check their submissions for the incidence of such long equations and break the equations at the correct places so that the final typeset copy will be as they wish.