Photoacoustic Imaging Landscape Analysis

March, 2014
# Contents

Photoacoustic Imaging - Landscape Analysis .................................................................................. 3
Introduction .................................................................................................................................. 3
Methodology ................................................................................................................................. 3
  Patent search .............................................................................................................................. 3
  Assignment search ...................................................................................................................... 6
  Important notes: .......................................................................................................................... 7
Patent Landscape Analysis ............................................................................................................ 7
  Patent filing trends ..................................................................................................................... 7
  Top patent holders ..................................................................................................................... 7
  Top Assignee vs. Filing Year ........................................................................................................ 8
  Geographical distribution of patents .......................................................................................... 8
  Top CPC codes .......................................................................................................................... 9
  Top Assignee vs. CPC Code ....................................................................................................... 11
  Topic Map – Concepts ............................................................................................................... 12
  Topic Map – Technologies ......................................................................................................... 13
  Major industry and academic institutions holding patents in 'surgical applications' for photo acoustic imaging/tomography ............................................................... 13
Assignment landscape analysis .................................................................................................... 15
  Patent transaction trends ........................................................................................................... 15
  Top transacted assignors (Sellers) ............................................................................................ 15
  Top transacted assignees (Acquirers) ......................................................................................... 16
  Transaction Assignor vs. Assignee ............................................................................................ 16
  Top transaction assignee by executed year ................................................................................ 16
  Top transaction assignor by executed year ................................................................................. 17
Summary ...................................................................................................................................... 17
Disclaimer ..................................................................................................................................... 18
Photoacoustic Imaging- Landscape Analysis

Introduction

Photoacoustic Imaging (optoacoustic imaging) is an imaging technology based on the photoacoustic effect, and can be used for obtaining images of structures in turbid environments. The optoacoustic technique combines the accuracy of spectroscopy with the depth resolution of ultrasound. In photoacoustic imaging, non-ionizing laser pulses are delivered into biological tissues (when radio frequency pulses are used, the technology is referred to as thermoacoustic imaging). Some of the delivered energy is absorbed and converted into heat, leading to transient thermoelastic expansion and thus wideband (e.g. MHz) ultrasonic emission. The generated ultrasonic waves are then detected by ultrasonic transducers to form images.

This report aims to map out the patent landscape associated with Photoacoustic Imaging. This includes finding the major patent holders, geographical distribution of patents, top sub-technologies based on classification codes, sub-technology visualization using topic maps; as well as determining the patent transactions to obtain the key buyers and sellers in this technology area.

Relecura has been used to generate the data used in the various analyses and visualizations presented in this report.

Methodology

Patent search

1. We initiated the generation of the Photoacoustic Imaging patent landscape using the URL based raw text search of Relecura. The links given below were used for this purpose.
   http://en.wikipedia.org/wiki/Optoacoustic_imaging
   http://en.wikipedia.org/wiki/Photoacoustic_imaging_in_biomedicine

2. We then used “Seed Data” to look for the top representative classification codes, keywords, and concepts.
3. We similarly used “Explore” to look for additional keywords, concepts, and classification codes.

4. After identifying the relevant class codes from the above search, we used the “Class code Finder” and “Landscape” options, to retrieve any classification codes we might have missed.

5. We added or removed the keywords and concepts relevant or irrelevant to Photoacoustic Imaging from the Steps 2 through 4, to refine the results from Step 1. This step gave us **1,266 equivalents (2,258 documents)**.

6. We separately conducted a keyword search in the title, abstract, and claims along with relevant IPC and CPC codes using the “Advanced Search” interface, with the following search string:

\[
\text{IPC Codes: A61B 8/00, A61B 8/13, A61B 5/00, A61B 1/00, A61K 49/00, A61B 18/00, A61B 17/00, A61B 19/00, A61B 3/00, A61B 6/00, A61F 9/00, H04N 5/00, H04N 13/00, G01N 29/00, G01N 21/00, G01N 23/00, G01N 25/00, G01B 9/00, G01B 11/00, G01B 17/00, G06K 9/00, G06T 11/00, G06T 15/00, G06T 19/00, G06F 19/00}
\]

\[
\text{CPC codes: A61B 5/00, A61B 8/00, A61B 3/00, A61B 6/00, A61B 18/00, A61B 17/00, A61B 19/00, A61B 3/00, A61B 6/00, A61F 9/00, G01N 29/00, G01N 25/00, G01B 9/00, G06T 11/00, G06T 19/00, G06K 9/00, G01B 9/00, Y10S 128/0}
\]

This step provided us **3,731 equivalents (6,798 documents)**.

7. We separately conducted another keyword search in the full text along with relevant IPC and CPC codes using the “Advanced Search” interface, with the search string given below.

\[
\text{“(Photoacoustic \ optoacoustic \ photothermal \ optothermal \ thermoacoustic OR \ (optical \ OR \ light \ OR \ radiation) AND \ (sound \ OR \ acoustic \ OR \ sonic)) \ AND \ (imaging \ OR \ tomography \ OR \ photography \ OR \ picturing \ OR \ scan \ OR \ radiography \ OR \ radiology)\”~5 \ OR \ “[(optical \ light \ radiation) \ (sound \ acoustic \ sonic)]\”~2 \ (imaging \ tomography \ photography \ picturing \ scan \ radiography \ radiology)\”~5}
\]
IPC Codes: A61B 8/00, A61B 8/13, A61B 5/00, A61B 1/00, A61K 49/00, A61B 18/00, A61B 17/00, A61B 19/00, A61B 3/00, A61B 6/00, A61F 9/00, H04N 5/00, H04N 13/00, G01N 29/00, G01N 21/00, G01N 23/00, G01N 25/00, G01B 9/00, G01B 11/00, G01B 17/00, G06K 9/00, G06T 11/00, G06T 15/00, G06T 19/00, G06F 19/00

CPC codes: A61B 5/00, A61B 8/00, A61B 3/00, A61B 6/00, A61B 18/00, A61B 2017/00, A61B 2019/00, A61K 49/00, A61B 2017/00, A61B 2018/00, A61K 41/00, A61N 2005/00, A61F 9/00, G01N 21/00, G01N 29/00, G01N 25/00, G01B 9/00, G06T 11/00, G06T 19/00, G06K 9/00, G01B 9/00, Y10S 128/00

This step gave us **3,290 equivalents (5,978 documents)**

8. All the results from step 5 to step 7 were saved individually and combined to get the super set of Photoacoustic Imaging related patents and this gave us **6,035 equivalents (11,052 documents)**.

9. After saving the super set of Photoacoustic Imaging, we conducted a keyword search for **surgical applications for photo acoustic imaging/tomography** in the title, abstract, and claims of the set obtained from Step 8 using the “Advanced Search” interface of Relecura, with the search strategy mentioned below. We combined this with relevant IPC and CPC codes for surgery to get the result, which consists of **2,131 applications (2,886 documents)**.

(surgery OR surgical)

IPC Codes: A61B 17/00, A61B 19/00, A61B 18/00, A61B 1/00, A61F 9/007, A61F 13/36

CPC codes: A61B 13/13 OR A61B 17/00 OR A61B 17/02 OR A61B 17/04 OR A61B 17/064 OR A61B 17/068 OR A61B 18/00 OR A61B 19/00 OR A61B 2017/00 OR A61B 2018/00 OR A61B 19/00 OR A61B 2217/00 OR A61B 2218/00 OR A61B 2505/05 OR A61F 2/1664 OR A61F 9/007 OR A61F 11/004 OR A61F 13/36 OR A61F 2002/300930 OR A61F 2002/4632 OR A61F 2002/4635 OR A61F 2007/101 OR A61F 2009/007 OR A61F 2210/0019 OR A61F 2250/0093 OR A61K 49/006 OR A61M 2001/006 OR A61N 0005/1015 OR G05B 2219/2617 OR G05B 2219/39389 OR G05B 2219/45117 OR G05B 2219/45171 OR H01R 2201/12 OR Y10S 128/00 OR Y10S 601/00 OR Y10S 602/00 OR Y10S 604/00 OR Y10S 606/00 OR Y10S
Assignment search

We searched the assignment database to understand the transactions that have been recorded for patents addressing Photoacoustic Imaging.

1. The final set generated from the patent search was migrated to the assignment search section of Relecura, to retrieve the transactions in the technology area of Photoacoustic Imaging. We found **2,411 transactions records**.

2. The raw data from the above step was scrubbed within Relecura to get a relatively clean set of assignment transfers arising out of genuine patent transactions. To clean-up the raw data related to recorded assignment transfers, we carried out the following steps:

   a) The assignment transfers arising from a "change of name" were removed.

   b) The assignment transfers from companies to banks, as collateral or security for financing, were not considered.

   **Note:** For above steps (a and b) we used *Conveyance filed* in “Advanced Search” interface of Relecura with the following string and removed from result set to get a clean set.

   ("change of name" OR security OR release OR lien OR correction)

   c) Inter-subsidiary transactions and transactions between parent companies and their subsidiaries were not considered.

   d) Inventor assignments (to the parent company) were not considered for this analysis.

   **Note:** For above steps (c and d) we used "Browse feature" of Relecura and removed the inter-subsidiary transactions as well as inventor/individual assignments from search to get clean set.

3. After cleaning the transaction records using the above procedure, we were left with **1,199 assignment transfers**.

The results from the patent search and assignment search were used in the following analyses.
Important notes:

a) The analysis of this report is based on the patent assets of various geographies, assignment transfer data provided by the USPTO, and related corporate information available in the public domain. All patent counts mentioned should only be considered indicative.

b) The graphs are based on a preliminary analysis as outlined above. The patent set may need to be refined, and the search strategy tweaked, to make the analysis more comprehensive.

Patent Landscape Analysis

Patent filing trends

![Figure 1. Filing trends for patents in Photoacoustic imaging. The decline post 2011 is most likely due to the fact that filings in this period are yet to be published.](image)

Top patent holders

![Figure 2. Top asset holders in Photoacoustic imaging patents.](image)
Top Assignee vs. Filing Year

The above graph indicates that the filings in this technology area have consistently increased during the last decade. CANON tops the list of patent holders although its earliest filing is relatively recent (1993) as compared to others. Filings of some of the assignees like MALLINCKRODT have tapered off in recent years, while others have been consistently active in the area.

Geographical distribution of patents

The chart given below provides the distribution of patents and applications by geography. The graph indicates that U.S. and Europe followed by china are the top patent filing countries in Photoacoustic imaging. A good number of PCT applications are also filed in this technology area.
Figure 5. Geographical split of patent applications by top assignees in Photoacoustic imaging.

Top CPC codes

Figure 6. Top CPC codes of Photoacoustic imaging patents.
<table>
<thead>
<tr>
<th>CPC Class Code</th>
<th>Description</th>
<th>CPC Class Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A61B 5/0095</td>
<td>Detecting, measuring or recording for diagnostic purposes; Identification of persons &gt; Detecting, measuring or recording by applying one single type of energy and measuring its conversion into another type of energy &gt; by applying light and detecting acoustic waves, i.e. photoacoustic measurements</td>
<td>G01N 29/2418</td>
<td>Investigating or analysing materials by the use of ultrasonic, sonic or infrasonic waves; Visualisation of the interior of objects by transmitting ultrasonic or sonic waves through the object &gt; Details; e.g. general constructional or apparatus details &gt; Probes &gt; using optoacoustic interaction with the material, e.g. laser radiation, photoacoustics</td>
</tr>
<tr>
<td>A61B 8/12</td>
<td>Diagnosis using ultrasonic, sonic or infrasonic waves &gt; In body cavities or body tracts, e.g. by using catheters</td>
<td>A61B 2019/5276</td>
<td>Instruments, implements or accessories for surgery or diagnosis not covered by any of the groups A61B1/00 to A61B17/00, e.g. for stereotaxis, sterile operation, luxation treatment, wound edge protectors &gt; Image-producing devices or illumination devices not otherwise provided for, e.g. operation microscopes; Operation lamp handles &gt; Surgical systems with images on a monitor during operation &gt; ultrasound</td>
</tr>
<tr>
<td>G01N 21/1702</td>
<td>Investigating or analysing materials by the use of optical means, i.e. using infra-red, visible, or ultra-violet light &gt; Systems in which incident light is modified in accordance with the properties of the material investigated &gt; with opto-acoustic detection, e.g. for gases or analysing solids</td>
<td>A61B 8/00</td>
<td>Diagnosis using ultrasonic, sonic or infrasonic waves</td>
</tr>
<tr>
<td>A61B 5/0059</td>
<td>Detecting, measuring or recording for diagnostic purposes; Identification of persons &gt; using light, e.g. diagnosis by transillumination, diascopy, fluorescence</td>
<td>A61B 8/08</td>
<td>Diagnosis using ultrasonic, sonic or infrasonic waves &gt; Detecting organic movements or changes, e.g. tumours, cysts, swellings</td>
</tr>
<tr>
<td>A61B 19/5244</td>
<td>Instruments, implements or accessories for surgery or diagnosis not covered by any of the groups A61B1/00 to A61B17/00, e.g. for stereotaxis, sterile operation, luxation treatment, wound edge protectors &gt; Image-producing devices or illumination devices not otherwise provided for, e.g. operation microscopes; Operation lamp handles &gt; Surgical systems with images on a monitor during operation &gt; Systems for tracking the position of an instrument during image guided surgery, e.g. surgical navigation systems</td>
<td>A61N 7/02</td>
<td>Ultrasound therapy &gt; Localised ultrasound hyperthermia</td>
</tr>
</tbody>
</table>
Figure 7. Top Patent Holders in the relevant CPC codes for Photoacoustic imaging.

Table 2. Description of CPC codes mentioned in Figure 7.

<table>
<thead>
<tr>
<th>CPC Class Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A61B 5/0095</td>
<td>Detecting, measuring or recording for diagnostic purposes; Identification of persons &gt; using light, e.g. diagnosis by transillumination, diascopy, fluorescence</td>
</tr>
<tr>
<td>G01N 21/1702</td>
<td>Investigating or analysing materials by the use of optical means, i.e. using infra-red, visible, or ultra-violet light &gt; Systems in which incident light is modified in accordance with the properties of the material investigated &gt; with opto-acoustic detection, e.g. for gases or analysing solids</td>
</tr>
<tr>
<td>A61B 5/0059</td>
<td>Detecting, measuring or recording for diagnostic purposes; Identification of persons &gt; using light, e.g. diagnosis by transillumination, diascopy, fluorescence</td>
</tr>
<tr>
<td>A61B 8/00</td>
<td>HUMAN NECESSITIES &gt; MEDICAL OR VETERINARY SCIENCE; HYGIENE &gt; DIAGNOSIS; SURGERY; IDENTIFICATION &gt; Diagnosis using ultrasonic, sonic or infrasonic waves</td>
</tr>
<tr>
<td>G01N 29/2418</td>
<td>Investigating or analysing materials by the use of ultrasonic, sonic or infrasonic waves; Visualisation of the interior of objects by transmitting ultrasonic or sonic waves through the object &gt; Details; e.g. general constructional or apparatus details &gt; Probes &gt; using optoacoustic interaction with the material, e.g. laser radiation, photoacoustics</td>
</tr>
<tr>
<td>A61B 19/5244</td>
<td>Instruments, implements or accessories for surgery or diagnosis not covered by any of the</td>
</tr>
<tr>
<td>A61B 8/12</td>
<td>Diagnosis using ultrasonic, sonic or infrasonic waves &gt; In body cavities or body tracts, e.g. by using catheters</td>
</tr>
<tr>
<td>A61K 49/0056</td>
<td>Preparations for testing in vivo &gt; Preparation for luminescence or biological staining &gt; Luminescence &gt; Fluorescence in vivo &gt; characterised by the carrier molecule carrying the fluorescent agent &gt; Peptides, proteins, polyamino acids</td>
</tr>
<tr>
<td>A61B 5/0073</td>
<td>HUMAN NECESSITIES &gt; MEDICAL OR VETERINARY SCIENCE; HYGIENE &gt; DIAGNOSIS; SURGERY; IDENTIFICATION &gt; Detecting, measuring or recording for diagnostic purposes; Identification of persons &gt; using light, e.g. diagnosis by transillumination, diascopy, fluorescence &gt; by tomography, i.e. reconstruction of 3D images from 2D projections</td>
</tr>
<tr>
<td>A61B 5/4312</td>
<td>Detecting, measuring or recording for diagnostic purposes; Identification of persons &gt; Detecting, measuring or recording for evaluating the reproductive systems &gt; for evaluating the female reproductive systems, e.g. gynaecological evaluations &gt; Breast evaluation or disorder diagnosis</td>
</tr>
<tr>
<td>A61B 5/0091</td>
<td>Detecting, measuring or recording for diagnostic purposes; Identification of persons &gt; using light, e.g. diagnosis by transillumination, diascopy, fluorescence &gt; adapted for particular medical purposes &gt; for mammography</td>
</tr>
<tr>
<td>A61B 2019/5276</td>
<td>Instruments, implements or accessories for surgery or diagnosis not covered by any of the</td>
</tr>
</tbody>
</table>
### CPC Class Code | Description
--- | ---
A61B 8/08 | Diagnosis using ultrasonic, sonic or infrasonic waves > Detecting organic movements or changes, e.g. tumours, cysts, swellings
A61K 49/0032 | Preparations for testing in vivo > Preparation for luminescence or biological staining > Luminescence > Fluorescence in vivo > characterised by the fluorescent group > the fluorescent group being a small organic molecule > Methine dyes, e.g. cyanine dyes

### CPC Class Code | Description
--- | ---
 | the groups A61B1/00 to A61B17/00 , e.g. for stereotaxis, sterile operation, luxation treatment, wound edge protectors > Image-producing devices or illumination devices not otherwise provided for, e.g. operation microscopes; Operation lamp handles > Surgical systems with images on a monitor during operation > Systems for tracking the position of an instrument during image guided surgery, e.g. surgical navigation systems
A61N 7/02 | Ultrasound therapy > Localised ultrasound hyperthermia

#### Figure 9. Topic Map based on concepts.
Figure 10. Topic Map based on technologies.

Major industry and academic institutions holding patents in 'surgical applications' for photoacoustic imaging/tomography

Figure 11. Top companies holding patents in surgical applications for photoacoustic imaging.
Table 3. List of companies and number of patents shown in Fig 11.

<table>
<thead>
<tr>
<th>Normalized Current Assignee</th>
<th>Number of Documents</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEDTRONIC</td>
<td>53</td>
</tr>
<tr>
<td>PHILIPS</td>
<td>53</td>
</tr>
<tr>
<td>SIEMENS</td>
<td>53</td>
</tr>
<tr>
<td>GENERAL ELECTRIC</td>
<td>36</td>
</tr>
<tr>
<td>MALLINCKRODT</td>
<td>32</td>
</tr>
<tr>
<td>BOSTON SCIENTIFIC</td>
<td>29</td>
</tr>
<tr>
<td>OLYMPUS</td>
<td>24</td>
</tr>
<tr>
<td>GEN HOSPITAL CORP</td>
<td>16</td>
</tr>
<tr>
<td>INVENTION SCIENCE FUND I LLC</td>
<td>15</td>
</tr>
<tr>
<td>KONA MEDICAL INC</td>
<td>15</td>
</tr>
</tbody>
</table>

Table 4. List of universities/academic institutions and number of patents.

<table>
<thead>
<tr>
<th>Normalized Current Assignee</th>
<th>Number of Documents</th>
</tr>
</thead>
<tbody>
<tr>
<td>NATIONAL INSTITUTES OF HEALTH</td>
<td>20</td>
</tr>
<tr>
<td>UNIVERSITY OF CALIFORNIA</td>
<td>18</td>
</tr>
<tr>
<td>UNIVERSITY OF WASHINGTON</td>
<td>14</td>
</tr>
<tr>
<td>UNIV TEXAS</td>
<td>11</td>
</tr>
<tr>
<td>JOHNS HOPKINS UNIVERSITY</td>
<td>9</td>
</tr>
<tr>
<td>UNIVERSITY OF MICHIGAN</td>
<td>8</td>
</tr>
<tr>
<td>KARMANOS B A CANCER INST</td>
<td>5</td>
</tr>
<tr>
<td>GEORGIA TECH RES INST</td>
<td>4</td>
</tr>
<tr>
<td>INST NAT SANTE RECH MED</td>
<td>4</td>
</tr>
<tr>
<td>STANFORD RES INST INT</td>
<td>4</td>
</tr>
</tbody>
</table>
Assignment landscape analysis

The USPTO’s assignment dataset was searched for various transactions carried out on patents addressing Photoacoustic imaging and the results of the search are used to create a transaction landscape.

Patent transaction trends

![Graph showing overall transaction trend for patents in Photoacoustic imaging.](image)

*Figure 12. Overall transaction trend for patents in Photoacoustic imaging.*

Top transacted assignors (Sellers)

![Graph showing top normalized transaction assignors.](image)

*Figure 13. Top transaction assignors (Sellers) in Photoacoustic imaging.*
Top transacted assignees (Acquirers)

Figure 14. Top transaction assignees (acquirers) in Photoacoustic imaging.

Transaction Assignor vs. Assignee

Figure 15. Assignment transfer matrix — Assignor vs. Assignee for Photoacoustic imaging patents.

Top transaction assignee by executed year

Figure 16. Buyers for patents in Photoacoustic imaging with trends.
Summary

The patent filings in Photoacoustic Imaging technologies have been witnessing a steady increase since 1997. Currently, Canon and Philips emerge as the top two players. While, the US and Europe lead the race geographically, a substantial number of PCT applications have also been filed.

In the landscape analysis, ‘Medical imaging’ and ‘Ultrasound’ are the most occurring concepts, and ‘Diagnosis and Surgery identification’ emerges as the top sub-technology with over 3,000 patent assets. If we dive deeper into this sub-technology, Medtronic, Philips, and Siemens stand together as the top patent asset holders with 53 patent assets each. On the other hand, with regard to universities and research institutions, National Institutes of Health (NIH) and University of California lead with 20 and 18 assets respectively.

NIH also has a significant number of patents assigned to it with over 140 recorded assignment transfers in the Photoacoustic Imaging domain. These assets are most likely the result of research funded by it in various universities and R&D institutions. Searate and University of California turn out to be the top two Assignors (sellers).
About Relecura

Relecura is the flagship product of INDUS TechInnovations. It is a web-based patent and portfolio analysis platform that uses a knowledge discovery framework to simplify IP analysis for prior art searches and IP commercialization activities. For more details visit www.relecura.com or write to us at info@relecura.com.

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