field may be designed as a solenoid The coils for the transverse magnetic fields may be designed as sets of Helmholtz coils.

FIG. **9**(*a*), FIG. **9**(*b*), FIG. **9**(*c*), and FIG. **9**(*d*) illustrate a schematic of the main NMRG **800** components, including **9**(*a*) NMR cell **805** etched in silicon **810** and bonded between two layers of Pyrex **815**, FIG. **9**(*b*) base-plate (**825**) containing VCSEL **830** and photodiodes **835** with microflex circuit **840** for interconnects, FIG. **9**(*c*) assembled NMRG **850**, and **9**(*d*) cross-sectional view of assembled NMRG **850** in accordance with one embodiment of the present invention.

The vapor cell is similar to the cells previously used in chip-scale atomic clocks. FIG. **9**(*a*) shows the cell components before assembly. A thick (~1 mm) silicon wafer **810** is first anisotropically through-etched, using for example KOH. Once the silicon is etched, highly reflective mirrors may optionally be deposited on the cell walls to increase the strength of the signal received by the photodiodes. Next, a thin layer of Pyrex glass **815** is anodically bonded to the etched silicon **810**. The cell **805** is then filled with an alkali metal as well as noble gases. Finally, a second layer of Pyrex **815** is used to seal the cell using anodic bonding. The spacer **820** in FIG. **9**(*a*) is either etched or machined and is used to provide a significant space between the electrical components on the base-plate and the cell in order to minimize residual magnetic fields in the cell and optimize the distance from the cell to the laser for the diverging beam geometry. The spacer **820** is also used to simplify the relative alignment between the optical components on the base-plate (FIG. **9**(*b*)) and the cell **805**. Both the side length and the height of the assembly in FIG. **9**(*a*) are on the order of a few millimeters.

FIG. **9**(*b*) shows the base-plate **825** on which all of the electrical components are attached. The light source is a vertical-cavity surface-emitting laser (VCSEL) **830**, located in the center of the base plate. The cathode of the VCSEL **830** is located on the backside of the chip and is attached to the base plate using, for example, solder bump bonding. The anode of the VCSEL **830** is located on the front side of the chip and is connected to the base-plate with a small wire-bond (not shown). Four flip-chip bonded, back-illuminated photodiodes **835** are used to detect the reflected light intensity. All of the pads of these photodiodes **835** are facing the base-plate **825** and may be solder bump bonded to achieve electrical contacts. Alternatively, the photodiodes (and potentially also the VCSEL **830**) may be integrated directly in the base-plate **825** material, which would eliminate the need for die attachment and solder bumping. The flex circuit **840** may be fabricated using a photo definable polyimide. This flex is needed in order to provide interconnects from the base-plate **825**, through the hole in the magnetic shield, and to the external signal conditioning and detection circuitry which can be provided via a computer as shown in FIG. **12**

A few other components need to be integrated with the parts shown in FIG. **9**(*b*). First, a quarter-wave plate needs to be placed on top of the VCSEL **830** to convert the linearly polarized light emitted by the VCSEL **830** to circularly polarized light. The wave plate can be placed directly on top of the VCSEL **830** using a small holder or alternatively in between the spacer and the NMR cell. In addition, a heater **855** is also needed in order to heat the cell to a temperature at which a sufficient rubidium vapor pressure is achieved (about 100° C.). The heater **855** can be implemented as traces on the base-plate **825**, or alternatively a separate heater chip may be used. Furthermore, a thermal sensor **860** is needed in order to stabilize the temperature at a predetermined value. Similarly to the heater, this sensor may be integrated on the base-plate **825** or designed as a separate chip placed in close proximity to the parts in FIG. **9**(*b*).

FIG. **9**(*c*) depicts how the cell and spacer is aligned and attached to the base-plate. A cross-sectional view of this is displayed in FIG. **9**(*d*), where a portion of the light **845** path is also illustrated. Note that the central part of the light **845** beam, used for optical pumping, will travel straight through the cell **805** and exit through the small opening on the top.

FIG. **10**(*a*) and FIG. **10**(*b*) illustrate a schematic of a base plate **960** with flex circuit **910** after the electrical components have been attached and a cross-sectional view of the fabrication process for the base plate **960** with flex circuit **910** in accordance with one embodiment of the present invention. FIG. **10**(*a*) depicts an expanded view of the base-plate **960** that was illustrated in FIG. **9**(*b*), showing the full length of the flex circuit **910**. As shown in FIG. **10**(*b*), this part is fabricated on top of a silicon wafer **920** by first patterning a highly flexible material **930**, such as photo definable polyimide. Next, in step **2**, traces of a highly conductive material **940** (e.g., aluminum, copper, or gold) are defined on top of the polyamide **930** (using, for example, a liftoff process). In the same processing step, bonding pads **950** are defined on both the base-plate **960** (for die attachment and wire-bonding) as well as on the tail end of the flex which can be adapted to connect components on the base-plate to external circuitry (e.g., a computer). Optionally, electroplating may also be employed to increase the thickness of the conductors. In Step **3**, a second layer of polyimide **930** is patterned on top of the conductors (with openings for all of the bonding pads on the base-plate and on the tail end of the flex). In the fourth and final processing step, the silicon wafer **920** is etched everywhere except for underneath the base-plate **960**, using, for example, deep-reactive ion etching. After this step a flex circuit **910** with highly flexible insulated conductors that can be threaded through the magnetic shields is obtained.

FIG. **11** illustrates a schematic of a wave plate **1010** integration and cell alignment in accordance with one embodiment of the present invention. A cutout is machined in the spacer **1040** allowing for alignment and integration of the quarter-wave plate **1010**. In addition, this figure also illustrates how the NMR cell **1020** can be actively aligned with respect to the components on the base plate **1030**. First, assume that the spacer **1040** has been affixed to the base plate **1030** (using epoxy, for example) and that the quarter-wave plate **1010** has been aligned with respect to the VCSEL in such a way that circularly polarized light is achieved. If suitable electrical signals are provided to the bonding pads on the tail end of the flex, the VCSEL and photodiodes can be operated. By temporarily affixing the top of the NMR cell to a stationary stage and at the same time affixing the bottom of the base-plate **1030** to a six-degree-of-freedom alignment stage, the cell can be aligned in such a way that the small opening on top of the cell is centered over the VCSEL and the magnitude of the signal received by all four photodiodes is equal. The cell can be affixed to the spacer **1040** at this position (using for example epoxy) and the assembled NMRG parts can then be removed from their temporary attachment to the alignment stage.

Referring to FIG. **12**, a system architecture **1100** is illustrated wherein a magnetometer **1010** is connected to a computer **1120**. The computer **1120** is adapted to function as external signal conditioning and detection circuitry facilities. Also shown is FIG. **12**, a Gyroscope **1030** can be coupled to a computer **1120**, when the sensor is provided in the form of a gyroscope **1130** as opposed to the magnetometer **1110**.