# Investigation of Concealed Explosive Detection by $^{14}$N–NQR

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*To avoid tragedies and wreckage caused by terrorists and to protect human's life and properties, the detection of concealed explosives at airports, railway stations, is highly demanded in the world, the detection of explosives concealed in luggage, parcel, and such is a challenge topic. This paper presents the development of Nuclear Quadrupole Resonance techniques at the China Institute of Atomic Energy.*

## 1. Objective and Significance of Explosive Detection

Along with world situation unstable, terror explosion has assumed rising tendency. Terrorists make use of concealed explosives to blackmail and threaten people, and hijack airplanes. Explosions of airplanes and trains occur sometimes. Especially, after the bombing of Pan American Flight 103 on 21 December, 1988 (Lockerbie air disaster), 270 dead. Many countries strengthen to the guard of aviation and explosive detection in customs. Explosive detection is a world issue. After Beijing successful winning of the bidding for the 2008 Olympic games, and will hold World's fair in 2010, China has emphasized the technique of explosive detection and given great importance to the subject. To avoid tragedies and wreckage caused by terrorists and to protect human's life and properties, the detection of concealed explosives at airports, railway stations, is highly demanded in the world, the detection of explosives concealed in luggage, parcel, etc is a challenge topic.

## 2. Present developing Status and Tendency

At present, the methods of explosive detection include x-ray detection, neutron detection, physics and chemistry detection, biology detection, electromagnetic detection.

### 2.1. X-ray Detection

X ray, $\gamma$ ray detection include x-ray, $\gamma$-ray transmission imaging method, Dual energy x-ray ,$\gamma$-ray method x-ray, $\gamma$-ray back scattering method, x-ray CT, etc. They belong to density identification and equivalent atomic number measurement, It is better to identify metal weapons, but finding explosives visually is hard, since most x-ray systems in use are not sensitive to the light elements H, C, N and O.

### 2.2. Neutron Detection

Neutron detection includes thermal neutron analysis method, pulsed fast neutron analysis method, pulsed fast and slow neutron analysis method, trace particle analysis method, pulsed neutron back scattering method, etc. Through exploring characteristic $\gamma$-ray to identify the contents of H, C, N, O in substances, the shell of scanner must have good defense for fear the radiation.

### 2.3. Physics, Chemistry, and Biology Detection

Physics and chemistry detection include chemistry fluorescence detection technology, high-speed gas chromatography (HSGC) technology, ion mobility spectroscopy analysis technology, gas chromatography detection, acoustic surface wave analysis, etc. Gas analysis detection detects the emanating particles, restricted in explosives which easy to send out, such as glycerin explosive. Using military explosive (plastic explosive) or taking measures to avoid particle sending out, gas analysis detection is helpless, its detection time is long, and can not online detection. Biology detection requires mostly using police dogs, fruit fly, and bee.

### 2.4. Electromagnetic Resonance Detection

Electromagnetic resonance detection include Nuclear Magnetic Resonance (NMR), Nuclear Quadruple Resonance (NQR), and dual resonance (nuclear magnetic resonance and nuclear quadruple resonance cross relaxation).

## 3. NQR Technical Development History

NQR is one kind of emerging detection technology in the recent several dozens years, its phenomenon is observed by N.F. Ramsey when he is doing halogenide molecular beam experiment in 1946. Until 1951, R.V. Pound and G.D. Watkins observed the resonance peak of $^{14}$N–NQR. In sixties of twenty century, American army need a kind of new technique very urgent to solve the non metal landmine detection, they think NQR technique has potential application foreground. So they give much support to NQR research work, which make NQR technique become more and more perfect, the sensitivity has been improved a lot.

After the bombing of Pan American Flight 103 on 21 December, 1988, the research work of detecting explosive in luggage has started. Until 1994, quanta magnetism company began to investigate the commercial equipment of explosive detection, they manufactured the first equipment in 1996, which was used in airport, but there are still some problems to be solved.

V.S. Grechishkin and his colleague who worked in Kaliningrad university had manufactured online monitoring equipment of explosive by NQR technique and landmine detection equipment by double resonance technique successfully.

## 4. Principle of $^{14}$N–NQR Detection

Most of explosives contain nitrogen (N), nitrogen atomic nucleus is a distortion nucleus, the distribution of it's charges is dissymmetry, it has quadrupole moment. The same $^{14}$N nucleus in different substances has different NOR frequency, furthermore, the difference is very big. So we use NQR technique to identify if the $^{14}$N nucleus in the substance being detected has certain NQR signal to judge if the luggage has explosives, and we also can identify which kind of explosive in the luggage.

NQR is based on the electric quadrupole interaction between the nuclear quadrupole moment and the extra electric field gradient (EFG). The EFG, hence the quadrupole resonance depends strongly on the molecular structure. Therefore, each substance is characterized by its own NQR frequency. So far, NQR has been observed from more than 30 nuclei. More than 10 thousands of substances have been investigated by the NQR technique and no identical NQR frequencies have been found.

All explosives contain nitrogen in which the abundance of N is 99.63%. N is a nice NQR probe nucleus. So $^{14}$N–NQR technique can be used to detect the explosives and has its own advantages.

## 5. Our Research Status in Explosive Detection at Present

With government's support, after several years research, CIAE has manufactured a static state prototype detection system and an on-line monitoring equipment of explosive RDX used in laboratory. Some research work of detecting TNT and drug is also being conducted.

The prototype detection system contains five units: Computer application software, Computer and Control, RF signal generator and power amplifier, Probe, Signal receive and amplify and Moving mechanical unit.

We have manufactured flat spiral wire coil, column coil, we find both of them can not meet our requirement by doing experiment. Finally, we design a ellipse shape coil, which has improved the field effectively.

We have developed three kinds of detection system, the sensitive volume and shape of their coils are different. The functions of three kinds of detection system is given in Table 1.

## 6. The Key Problems to be solved

The difficulties in explosive detection by $^{14}$N–NQR technology are numerous. The NQR signal emitted by $^{14}$N of explosive after excited by extra electric field gradient is very weak, its frequency

*Table 1: NQR experimental equipment*

| Equipment Type | High | Middle | Big |
|---|---|---|---|
| Sensitivity (RDX) | 1 g | 100 g | 100 g |
| Sensitive Volume | 0.5 l | 54 l | 150 l |
| Measured Time | 28 s | 12 s | 12 s |
| Fault Alarm Ratio | 3% | 3% | 3% |

range is low and wide, varied from hundreds kHz to several MHz. The frequency belongs to middle wave radio, so it's very easy interfered. NQR is a non-contact measurement technology, the distance between sample and probe is varied from several centimeters to decades centimeters, so the NQR signal is not only very weak, but also very unfixed.

In order to detect the NQR signal effectively, entire system need to shield environmental electric and magnetic field very well, low noise preamplifier, multi-grades filters, correlation demodulation, etc are needed, and the computer analysis software is important too.

Although laboratory experiment prototype equipment and channel type equipment have been developed successfully, but there exist some key problems to be solved in making these equipments been able to use in spot.

1. Significant improve the signal to noise ratio to meet the practical application requirements of detection sensitivity, speed and reliability.
2. Wide band RF signal power amplifier.
3. Signal process technology for very weak signal.
4. Computer control techniques.

## 7. Exchanges

Exploration concealed explosive is an important aspect in both guarding against terror and anti-terrorist. Every country around the world always takes much account of the research on detection concealed explosive, especially after September 11 attacks, they all increase the fund and human resource on this subject.

The research, detection explosive by $^{14}$N–NQR technology, have been done for several years in CIAE, and a good technical team has also been formed. After Beijing city succeeded in applying for holding 29th Olympic Games, China Governments have paid more attentions on explosive detection and also provided more research fund.

According to the requirement of antiterrorist and to safeguard the Olympic Games, we should develop and manufacture the practicable on-line monitoring equipment based on the prototype equipment as soon as possible, and install these equipments at airplane port, railway station, passenger ship port, stadiums of Olympic Games and all around, etc.

So, we sincerely hope we can discuss and communicate this subject with you and your laboratory, and expect our colleagues have the chance to learn new technology in your laboratory, in particular on these key techniques, such as tune, signal process and RF amplifier. Of course, everyone is welcomed to China to visit our laboratory.

We also wish you can recommend us some useful information or components on NQR technology, such as NQR spectrometer, RF power amplifier, etc. We expect we can cooperate with you.

## Acknowledgments

Detection concealed explosive is a concerned problem around the world. Along with the new security situation occurring on the world and new type explosives appearing, we will face more challenges.

We appreciate IAEA for giving us this chance to exchange ideas with experts coming from a lot of countries around the world, also appreciate IAEA for providing us technical and instrumental assistance by 2007–2008 TC program.

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